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1817

ELEMENTS

OF THE

Theory and Practice

OF

CHYMISTRY.

TRANSLATED

Pierre Joseph

From the French of M. MACQUER,

Member of the Royal Academy of Sciences, and Pro-
feſſor of Medicine in the Univerſity of Paris.

IN TWO VOLUMES.

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TO THE

RIGHT HONOURABLE

THE

Earl of B.U.T.E.

My LORD,

THIS Tranſlation of M. MACQUER's celebrated ELEMENTS of CHYMISTRY was undertaken with the ſole View of rendering ſome ſmall Service to my Country; as I hoped it might contribute both to recommend and to facilitate the Study of a SCIENCE, which, though more entertaining, inſtructive, and extenſively uſeful than any other, hath of late been too much neglected in this Iſland.

I think

DEDICATION.

I think myſelf very happy in ſeeing this Deſign approved of, and its Succeſs in a manner aſſured, by the Honour which YOUR LORDSHIP hath been pleaſed to do me, in condeſcending to take it under your Protection.

I am, with the utmoſt Reſpect,

MY LORD,

YOUR LORDSHIP'S

moſt Obedient

and moſt Humble Servant

London
March 25, 1758.

ANDREW REID.

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ELEMENTS

OF THE

THEORY of CHYMISTRY.

THE AUTHOR'S PREFACE.

AN hundred and fifty years are ſcarce elapſed ſince the clouds of prejudice, which had long overſpread the world, began to clear up, and men were convinced, by cultivating the Sciences and attending to Nature, that no fanciful hypotheſes would ever lead them to the true cauſes of thoſe various phenomena that inceſſantly and every where meet the obſerver's eye; but that the narrow limits of the human underſtanding confine the courſe of our reſearches to one ſingle path; namely, that of Experiment, or the Uſe of our Senſes. Yet, in this ſhort period, Natural Philoſophy hath riſen to a high pitch of improvement, and may with truth be ſaid to have made much greater advances towards perfection, ſince the experimental method was introduced, than in the many ages before.

This is true with regard to every branch of Natural Philoſophy; but more particularly with regard to Chymiſtry. Though this Science cannot be ſaid to have ever exiſted without experiments, yet it laboured under the ſame diſadvantages with the reſt; becauſe thoſe who ſtudied it made all their experiments with a view to confirm their own Hypotheſes, and in conſequence of principles which had no foundation but in their imaginations.

Hence aroſe that enormous heap, that incongruous jumble of facts, which ſome time ago conſtituted all the knowledge of Chymiſts. Moſt of them, and eſpecially thoſe who aſſumed the pompous title of Alchymiſts, were perſuaded that all the Metals were no other than Nature's rude unfiniſhed eſſays towards making Gold; which, by means of due coction in the bowels of the earth, advanced gradually towards maturity, till at laſt they became perfectly like that beautiful and precious Metal.

On this principle, which, if not demonſtrably falſe, is at leaſt utterly deſtitute of proof, and unſupported by a ſingle obſervation, they attempted to finiſh what Nature had begun, by procuring to the imperfect Metals this much deſired coction. To attain it they made an infinite number of experiments and trials; which all conſpired to detect the falſity of their ſyſtem, and to ſatisfy men of ſenſe that the methods they employed were very far from anſwering the purpoſe.

However, as facts always promote the knowledge of Nature, it happened that thoſe experiments, though quite uſeleſs with regard to the end for which they were originally made, proved the occaſion of ſeveral curious diſcoveries.

Theſe lucky conſequences of their miſtaken labours raiſed the courage of the Chymiſts, or rather Alchymiſts, who looked upon every ſuch inſtance of ſucceſs as a new ſtep towards the Grand Work, and greatly increaſed the fond opinion they entertained of themſelves, and of their Art, which on that account they ſet up very high above all other Sciences. Nay, they carried this notion of ſuperiority ſo far, as to hold the reſt of mankind unworthy, or incapable, of riſing to ſuch ſublime knowledge. In conſequence thereof Chymiſtry became an occult and myſterious Science; its expreſſions were all tropes and figures, its phraſes metaphorical, and its axioms ſo many enigmas: in ſhort, an obſcure unintelligible jargon is the juſteſt character of the Alchymiſtic Language.

Thus, by endeavouring to conceal their ſecrets, thoſe gentlemen rendered their Art uſeleſs to mankind, and brought it into deſerved contempt. But at length the genius of true Philoſophy prevailed in Chymiſtry, as well as in the other Sciences. Some great men aroſe, who had generoſity enough to think their knowledge no otherways valuable than as it proved of ſervice to Society. They did their utmoſt to introduce both the knowledge and the practice of many important ſecrets, till then of no uſe; they drew aſide the veil which hid the charms of Chymiſtry; and that Science emerging from the profound obſcurity, in which it had for many ages lain concealed, gained the admiration of the world as ſoon as it appeared in open day. Several ſocieties of ingenious men were formed in the moſt learned countries of Europe, who vied with one another in their labours to execute the noble ſcheme, and aſſiſted each other by mutually communicating their diſcoveries. Chymiſtry made the moſt rapid progreſs, enriching and perfecting the Arts derived from, or depending on it. In a word, it put on a new face, and became truly worthy of the title of Science; founding its principles and its proceſſes on ſolid experiments, and on juſt conſequences deduced from them.

Since that time the Art is rendered ſo extenſive, by the numerous diſcoveries which Chymiſts have already made, and are daily making, that large volumes are required to contain a complete Treatiſe on that ſubject. In ſhort, Chymiſtry may now, in ſome degree, be compared to Geometry: each of theſe Sciences takes in a moſt ample field of enquiry, which every day enlarges very conſiderably; from each are derived ſeveral Arts, not only uſeful but even neceſſary to Society; each hath its Axioms and its undeniable principles, either demonſtrated from internal evidence, or founded on conſtant experience; ſo that the one, as well as the other, may be reduced to certain fundamental truths, on which all the reſt are built. Theſe fundamental truths connected together, and laid down with order and preciſion, form what we call the Elements of a Science. It is well known that there are many ſuch works relating to Geometry, but it is not ſo with regard to Chymiſtry; there being very few books which treat of this Science in an Elementary manner.

Yet it muſt be owned that performances of this kind are exceedingly uſeful. Many who have a reliſh for the Sciences, but have not leiſure to read elaborate Works which treat of them minutely, are glad to meet with a book from which, without ſacrificing too much of their time, or neglecting their ordinary buſineſs, they may obtain a taſte or juſt notion of a Science that is not their principal ſtudy. Thoſe who incline to go further, and learn more, may, by reading an elementary tract, be enabled to underſtand Authors who, as they commonly write only for proficients in the Art, are obſcure and hardly intelligible to mere beginners. Nay, I preſume to ſay that an Elementary Treatiſe of Chymiſtry may prove a very uſeful book, even to thoſe who have made ſome progreſs in the Science: for as it contains only the fundamental propoſitions, and indeed is an abſtract of the whole Art, it may help them to recollect the moſt important parts of what they have read in many different works, and fix in their memories the moſt eſſential truths, which might elſe be either confounded with others, or entirely forgot. And theſe are the motives which determined me to compoſe the Work which I now offer to the Publick.

The general Plan on which I proceed is to ſuppoſe my Reader an abſolute Novice in Chymiſtry; to lead him from the moſt ſimple truths, and ſuch as imply the loweſt degree of knowledge, to ſuch as are more complex, and require a greater acquaintance with Nature. This order, which I have laid down for my rule, hath obliged me to begin with examining the moſt ſimple ſubſtances that we know, and which we conſider as the elements whereof others are compoſed; as, by knowing the properties of theſe elementary parts, we are naturally led to thoſe of their ſeveral combinations; and on the other hand, in order to know the properties of compound bodies, it is neceſſary we ſhould be firſt acquainted with the properties of their principles. The ſame reaſon induced me, when enquiring into the properties of one ſubſtance, to take no notice of thoſe which relate to any other ſubſtance not treated of before. For example: as I treat of Acids before Metals, I ſay nothing under the head of thoſe Acids concerning their power of diſſolving Metals: that I defer till I come to the ſubject of Metals: and thus I avoid ſpeaking prematurely of a ſubſtance with which I ſuppoſe my Reader wholly unacquainted. And this method I was ſo much the more eaſily induced to follow that I know of no Chymical book written on the ſame Plan.

After diſcourſing of Elements in general, I treat next of ſuch ſubſtances as are immediately compoſed of them, and are, next to them, the moſt ſimple: ſuch are all ſaline ſubſtances. This head comprehends mineral Acids, fixed Alkalis, and their ſeveral combinations; the volatile ſulphureous ſpirit, ſulphur, phoſphorus, and the Neutral ſalts which have an earth or fixed Alkali for their baſis;

thoſe which have for their baſis either a volatile Alkali, or ſome metallic ſubſtance, are referred, according to my general Plan, to the heads under which I treat of thoſe ſubſtances.

Metallic ſubſtances are ſcarce more compounded than the ſaline; which induces me to conſider them next. I begin with thoſe which are the moſt ſimple, or at leaſt ſeem to be ſo, becauſe their principles, being very ſtrongly connected together, are ſeparated with the greateſt difficulty: ſuch are the Metals properly ſo called; namely Gold, Silver, Copper, Iron, Tin, and Lead. After theſe come the Semi-metals in order; to wit, Regulus of Antimony, Zinc, Biſmuth, and Regulus of Arſenic. Mercury being a doubtful ſubſtance, which ſome Chymiſts rank with the Metals, and others with the Semi-metals, becauſe it actually poſſeſſes certain properties in common with each, I have treated of it in a ſeparate Chapter, which ſtands between the Metals and Semi-metals.

I next proceed to examine the ſeveral ſorts of Oils, whether Vegetable, which are divided into fat, eſſential, and empyreumatic; or Animal, and Mineral Oils.

By examining theſe ſubſtances we obtain ideas of all the principles which enter into the compoſition of Vegetable and Animal bodies; that is, of thoſe ſubſtances that are capable of fermentation: this enables me to treat of fermentation in general; of its three different degrees or kinds, the ſpirituous, acetous, and putrid; and of the products of thoſe fermentations, ardent ſpirits, acids analogous to thoſe of vegetables and animals, and volatile alkalis.

The order in which I treat of all thoſe ſubſtances being different from that in which they are obtained from compound bodies, I give, in a diſtinct Chapter, a general Idea of Chymical Decompoſition, with a view to ſhew the order in which they are ſeparated from the ſeveral bodies in the compoſition whereof they are found. This brings them a ſecond time under review, and gives me an opportunity of diſtinguiſhing thoſe which exiſt naturally in compound bodies, from thoſe which are only the reſult of a new combination of ſome of their principles produced by the fire.

The ſucceeding Chapter explains the late Mr. Geoffroy's Table of Affinities; which I take to be of great uſe at the end of an Elementary Tract like this, as it collects into one point of view the moſt eſſential and fundamental doctrines which are diſperſed through the work.

I conclude with an account of the Conſtruction of ſuch Veſſels and Furnaces as are uſually employed in Chymiſtry.

In this Part I ſay nothing of any manual operations, or the ſeveral ways of performing Chymical proceſſes; reſerving theſe particulars for my Treatiſe of Practical Chymiſtry, to which this muſt be conſidered as an Introduction.

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* * *

ELEMENTS

OF THE

THEORY of CHYMISTRY.

CHAP. I.

Of the PRINCIPLES *of Bodies.*

THE Object and chief End of Chymiſtry is to ſeparate the different ſubſtances that enter into the compoſition of bodies; to examine each of them apart; to diſcover their properties and relations; to decompoſe thoſe very ſubſtances, if poſſible; to compare them together, and combine them with others; to reunite them again into one body ſo as to reproduce the original compound with all its properties; or even to produce new compounds that never exiſted among the works of nature, from mixtures of other matters differently combined.

But this Analyſis, or Decompoſition, of Bodies is finite; for we are unable to carry it beyond a certain limit. In whatever way we attempt to go further, we are always ſtopped by ſubſtances in which we can produce no change, which are incapable of being reſolved into others, and which ſtand as ſo many firm barriers obſtructing our progreſs.

To theſe ſubſtances we may, in my opinion, give the title of Principles or Elements: at leaſt they are really ſuch with regard to us. Of this kind the principal are Earth, Water, Air, and Fire. For though there be reaſon to think that theſe are not the firſt component parts, or the moſt ſimple elements, of matter; yet, as we know by experience that our ſenſes cannot poſſibly diſcover the principles of which they are themſelves compoſed, it ſeems more reaſonable to fix upon them, and conſider them as ſimple homogeneous bodies, and the principles of the reſt, than to tire our minds with vain conjectures about the parts or elements of which they may conſiſt; ſeeing there is no criterion by which we can know whether we have hit upon the truth, or whether the notions we have formed are mere fancies. We ſhall therefore conſider theſe four ſubſtances as the principles or elements of all the various compounds which nature preſents to our enquiries: becauſe of all thoſe we know they are in fact the moſt ſimple; and becauſe all our decompoſitions, all our experiments on other bodies, plainly prove that they are at laſt reſolvable into theſe primary parts.

Theſe principles do not enter in the ſame proportion into all bodies: there are even ſome mixts in the compoſition of which this or that particular principle is not to be found. Thus Air and Water ſeem to be wholly excluded from the texture of Metals: at leaſt all the experiments hitherto made on them ſeem to eſtabliſh this opinion.

The ſubſtances compoſed immediately of theſe *Firſt* Elements we ſhall call *Secondary* Principles;

becauſe in reality their ſeveral combinations with each other, the interchangeable coalitions that take place between them, conſtitute the different natures of all other bodies; which, as they reſult from the union both of primary and ſecondary principles, are properly entitled to the name of Compounds or Mixts.

Before we enter upon the examination of Compound Subſtances, it is neceſſary to conſider the moſt Simple ones, or our four Firſt Principles, with ſome attention, in order to diſcover their chief properties.

§. I. *Of* AIR.

AIR is that Fluid which we conſtantly breathe, and which encompaſſes the whole ſurface of the terreſtrial globe. Being heavy, like all other bodies, it penetrates into all places that are not either abſolutely inacceſſible, or filled with ſome other body heavier than itſelf. Its principal property is to be ſuſceptible of condenſation and rarefaction; ſo that the very ſame quantity of Air may occupy a much greater, or a much ſmaller ſpace, according to the different ſtate it is in. Heat and cold, or, if you will, the preſence and the abſence of the particles of Fire, are the moſt uſual cauſes, and indeed the meaſures, of its condenſation and rarefaction: for if a certain quantity of Air be heated, its bulk enlarges in proportion to the degree of heat applied to it; the conſequence whereof is that the ſame ſpace now contains fewer particles of Air than it did before. Cold again produces juſt the contrary effect.

On this property which Air has, of being condenſed and dilated by heat, its elaſticity chiefly depends. For if Air were forced by condenſation into a leſs compaſs than it took up before, and then expoſed to a very conſiderable degree of cold, it would remain quite inactive, without exerting ſuch an effort as it uſually makes againſt the compreſſing body. On the other hand, the elaſticity of heated Air ariſes only from hence, that being rarefied by the action of fire, it requires much more room than it occupied before.

Air enters into the compoſition of many ſubſtances, eſpecially vegetable and animal bodies: for by analyſing moſt of them ſuch a conſiderable quantity thereof is extricated, that ſome naturaliſts have ſuſpected it to be altogether deſtitute of elaſticity when thus combined with the other principles in the compoſition of bodies. According to them the efficacy of the elaſtic power of the Air is ſo prodigious, and its force when compreſſed ſo exceſſive, that it is not poſſible the other component parts of bodies ſhould be able to confine ſo much of it in that ſtate of compreſſion which it muſt needs undergo, if retaining its elaſticity it were pent up among them.

However that be, this elaſtic property of the Air produces the moſt ſingular and important phenomena obſervable in the reſolution and compoſition of bodies.

§. II. *Of* WATER.

WATER is a thing ſo well known, that it is almoſt needleſs to attempt giving a general idea of it here. Every one knows that it is a tranſparent, inſipid ſubſtance, and uſually fluid. I ſay it is uſually ſo; for being expoſed to a certain degree of cold it becomes ſolid: ſolidity therefore ſeems to be its moſt natural ſtate.

Water expoſed to the fire grows hot; but only to a limited degree, beyond which its heat never riſes, be the force of fire applied to it ever ſo violent: it is known to have acquired this degree of heat by its boiling up with great tumult. Water cannot be made hotter, becauſe it is volatile, and incapable of enduring the heat without being evaporated and entirely diſſipated.

If ſuch a violent and ſudden heat be applied to Water as will not allow it time to exhale gently in vapours, as when, for inſtance, a ſmall quantity thereof is thrown upon a metal in fuſion, it is diſſipated at once with vaſt impetuoſity, producing a moſt terrible and dangerous exploſion. This ſurpriſing effect may be deduced from the inſtantaneous dilatation of the parts of the Water itſelf, or rather of the Air contained in it. Moreover, Water enters into the texture of many bodies, both compounds and ſecondary principles; but, like Air, it ſeems to be excluded from the compoſition of all metals, and moſt minerals. For although an immenſe quantity of Water exiſts in the bowels of the Earth, moiſtening all its contents, it does not therefore follow that it is one of the principles of minerals. It is only interpoſed between their parts; for they may be entirely robbed of it, without any ſort of decompoſition: indeed it is not capable of an intimate connection with them.

§. III. Of EARTH.

WE obſerved that the two principles above treated of are volatile; that is, the action of Fire ſeparates them from the bodies they help to compoſe, carrying them quite off, and diſſipating them. That of which we are now to ſpeak, namely Earth, is fixed, and, when it is abſolutely pure, reſiſts the utmoſt force of Fire. So that, whatever remains of a body, after it hath been expoſed to the power of the fierceſt Fire, muſt be conſidered as containing nearly all its earthy principle, and conſiſting chiefly thereof. I qualify my expreſſion thus for two reaſons: the firſt is, becauſe it often happens, that this remainder does not actually contain all the Earth which exiſted originally in the mixt body decompoſed by Fire; ſince it will afterwards appear that Earth, though in its own nature fixed, may be rendered volatile by being intimately united with other ſubſtances which are ſo; and that, in fact, it is common enough for part of the Earth of a body to be thus volatilized by its other principles: the ſecond is, that what remains after the calcination of a body is not generally its Earth in perfect purity, but combined with ſome of its other principles, which, though volatile in their own natures, have been fixed by the union contracted between it and them. We ſhall, in the ſequel, produce ſome examples to illuſtrate this theory.

Earth therefore, properly ſo called, is a fixed principle which is permanent in the Fire. There is reaſon to think it very difficult, if not impoſſible, to obtain the terrene principle wholly free from every other ſubſtance: for after our utmoſt endeavours to purify them, the Earths we obtain from different compounds are found to have different properties according to the different bodies from which they are procured; or elſe, if thoſe Earths be pure, we muſt allow them to be eſſentially different, ſeeing they have different properties.

Earth, in general, with regard to its properties, may be diſtributed into *fuſible*, and *unfuſible*; that is, into Earth that is capable of melting or becoming fluid in the Fire, and Earth that conſtantly remains in a ſolid form, never melting in the ſtrongeſt degree of heat to which we can expoſe it.

The former is alſo called *vitrifiable*, and the ſecond *unvitrifiable* Earth; becauſe, when Earth is melted by the force of fire, it becomes what we call *glaſs*, which is nothing but the parts of Earth brought into nearer contact, and more cloſely united by the means of fuſion. Perhaps the Earth, which we look upon as uncapable of vitrification, might be fuſed if we could apply to it a ſufficient degree of heat. It is at leaſt certain that ſome Earths, or ſtones, which ſeparately reſiſt the force of Fire ſo that they cannot be melted, become fuſible when mixed together. Experience convinced Mr du Hamel that lime-ſtone and ſlate are of this kind. It is however undoubtedly true that one Earth differs from another in its degree of fuſibility: and this gives ground to believe, that there may be a ſpecies of Earth abſolutely unvitrifiable in its nature, which, being mixed in different proportions with fuſible Earths, renders them difficult to melt.

Whatever may be in this, as there are Earths which we are abſolutely unable to vitrify, that is a ſufficient reaſon for our diviſion of them. Unvitrifiable Earths ſeem to be porous, for they imbibe Water; whence they have alſo got the name of *Abſorbent Earths.*

§. IV. *Of* FIRE.

THE Matter of the Sun, or of Light, the Phlogiſton, Fire, the Sulphureous Principle, the Inflammable Matter, are all of them names by which the Element of Fire is uſually denoted. But it ſhould ſeem, that an accurate diſtinction hath not yet been made between the different ſtates in which it exiſts; that is, between the phenomena of Fire actually exiſting as a principle in the compoſition of bodies, and thoſe which it exhibits when exiſting ſeparately and in its natural ſtate: nor have proper diſtinct appellations been aſſigned to it in thoſe different circumſtances. In the latter ſtate we may properly give it the names of Fire, Matter of the Sun, of Light, and of Heat; and may conſider it as a ſubſtance compoſed of infinitely ſmall particles, continually agitated by a moſt rapid motion, and of conſequence, eſſentially fluid.

This ſubſtance, of which the ſun may be called the general reſervoir, ſeems to flow inceſſantly from that ſource, diffuſing itſelf over the world, and through all the bodies we know; but not as a prinple, or eſſential part of them, ſince they may be deprived thereof, at leaſt in a great meaſure, without ſuffering any decompoſition. The greateſt change produced on them, by its preſence or its abſence, is the rendering them fluid or ſolid: ſo that all other bodies may be deemed naturally ſolid; Fire alone eſſentially fluid, and the principle of fluidity in others. This being preſuppoſed, Air itſelf might become ſolid, if it could be entirely deprived of the Fire it contains; as bodies of moſt difficult fuſion become fluid, when penetrated by a ſufficient quantity of the particles of Fire.

One of the chief properties of this pure Fire is to penetrate eaſily into all bodies, and to diffuſe itſelf among them with a ſort of uniformity and equality: for if a heated body be contiguous to a cold one, the former communicates to the latter all its exceſs of heat, cooling in exact proportion as the other warms, till both come to have the very ſame degree of heat. Heat, however, is naturally communicable ſooneſt to the upper parts of a body; and conſequently, when a body cools, the under parts become ſooneſt cold. It hath been obſerved, for inſtance, that the lower extremity of a heated body, freely ſuſpended in the air, grows cold ſooner than the upper; and that when a bar of iron is red-hot at one end, and cold at the other, the cold end is much ſooner heated by placing the bar ſo that the hot end may be undermoſt, than when that end is turned uppermoſt. The levity of the matter of Fire, and the vicinity of the Earth, may poſſibly be the cauſes of this phenomenon.

Another property of Fire is to dilate all bodies into which it penetrates. This hath already been ſhewn with regard to Air and Water; and it produces the ſame effect on Earth.

Fire is the moſt powerful agent we can employ to decompoſe bodies; and the greateſt degree of heat producible by man, is that excited by the rays of the ſun collected in the focus of a large burning-glaſs.

§. V. *Of the* PHLOGISTON.

FROM what hath been ſaid concerning the nature of Fire, it is evidently impoſſible for us to fix and confine it in any body. Yet the phenomena attending the combuſtion of inflammable bodies ſhew that they really contain the matter of Fire as a conſtituent principle. By what mechaniſm then is this fluid, which is ſo ſubtile, ſo active, ſo difficult to confine, ſo capable of penetrating into every other ſubſtance in nature; how comes it, I ſay, to be ſo fixed as to make a component part of the moſt ſolid bodies? It is no eaſy matter to give a ſatisfactory anſwer to this queſtion. But, without pretending to gueſs the cauſe of the phenomenon, let us reſt contented with the certainty of the fact, the knowledge of which will undoubtedly procure us conſiderable advantages. Let us therefore examine the properties of Fire thus fixed and become a principle of bodies. To this ſubſtance, in order to diſtinguiſh it from pure and unfixed Fire, the chymiſts have aſſigned the peculiar title of the *Phlogiſton*, which is indeed no other than a Greek word for the Inflammable Matter; by which latter name, as well as by that of the Sulphureous Principle, it is alſo ſometimes called. It differs from elementary Fire in the following particulars. 1. When united to a body, it communicates to it neither heat nor light. 2. It produces no change in its ſtate, whether of ſolidity or fluidity; ſo that a ſolid body does not become fluid by the acceſſion of the Phlogiſton, and *vice verſa*; the ſolid bodies to which it is joined being only rendered thereby more apt to be fuſed by the force of the culinary fire. 3. We can convey it from the body with which it is joined into another body, ſo that it ſhall enter into the compoſition thereof, and remain fixed in it.

On this occaſion both theſe bodies, that which is deprived of the Phlogiſton and that which receives it, undergo very conſiderable alterations; and it is this laſt circumſtance in particular that obliges us to diſtinguiſh the Phlogiſton from pure Fire, and to conſider it as the element of Fire combined with ſome other ſubſtance, which ſerves it as a baſis for conſtituting a kind of ſecondary principle. For if there were no difference between them, we ſhould be able to introduce and fix pure Fire itſelf whereever we can introduce and fix the Phlogiſton: yet this is what we can by no means do, as will appear from experiments to be afterwards produced.

Hitherto Chymiſts have never been able to obtain the Phlogiſton quite pure, and free from every other ſubſtance: for there are but two ways of ſeparating it from a body of which it makes a part; to wit, either by applying ſome other body with which it may unite the moment it quits the former; or elſe by calcining and burning the compound from which you deſire to ſever it. In the former caſe it is evident that we do not get the Phlogiſton by itſelf, becauſe it only paſſes from one combination into another; and in the latter, it is entirely diſſipated in the decompoſition, ſo that no part of it can poſſibly be ſecured.

The inflammability of a body is an infallible ſign that it contains a Phlogiſton; but from a body's not being inflammable, it cannot be inferred that it contains none: for experiments have demonſtrated that certain metals abound with it, which yet are by no means inflammable.

We have now delivered what is moſt neceſſary to be known concerning the principles of bodies in general. They have many other properties beſides thoſe above-mentioned; but we cannot properly take notice of them here, becauſe they preſuppoſe an acquaintance with ſome other things relating to bodies of which we have hitherto ſaid nothing; intending to treat of them in the ſequel as occaſion ſhall offer. We ſhall only obſerve in this place, that when animal and vegetable matters are burnt in ſuch a manner as to hinder them from flaming, ſome part of the Phlogiſton contained in them unites intimately with their moſt fixed earthy parts, and with them forms a compound that can be conſumed only by making it red-hot in the open air, where it ſparkles and waſtes away, without emitting any flame. This compound is called a *Coal.* We ſhall enquire into the properties of this Coal under the head of Oils: at preſent it ſuffices that we know in general what it is, and that it readily communicates to other bodies the Phlogiſton it contains.

CHAP. II.

A general View of the Relations or Affinities between Bodies.

BEFORE we can reduce compound Bodies to the firſt principles above pointed out, we obtain, by analyſing them, certain ſubſtances which are indeed more ſimple than the bodies they helped to compoſe, yet are themſelves compoſed of our primary principles. They are therefore at one and the ſame time both principles and compounds; for which reaſon we ſhall, as was before ſaid, call them by the name of Secondary Principles. Saline and oily matters chiefly conſtitute this claſs. But before we enter upon an examination of their properties, it is fit we lay before the Reader a general view of what Chymiſts underſtand by the Relations or Affinities of Bodies; becauſe it is neceſſary to know theſe, in order to a diſtinct conception of the different combinations we are to treat of.

All the experiments hitherto made concur with daily obſervation to prove that different bodies, whether principles or compounds, have ſuch a mutual Conformity, Relation, Affinity, or Attraction, if you will call it ſo, as diſpoſes ſome of them to join and unite together, while they are incapable of contracting any union with others. This effect, whatever be its cauſe, will enable us to account for, and connect together, all the phenomena that Chymiſtry produces. The nature of this univerſal affection of matter is diſtinctly laid down in the following propoſitions.

Firſt, If one ſubſtance has any Affinity or conformity with another, the two will unite together, and form one compound.

Secondly, It may be laid down as a general rule, that all ſimilar ſubſtances have an Affinity with each other, and are conſequently diſpoſed to unite; as water with water, earth with earth, *&c.*

Thirdly, Subſtances that unite together loſe ſome of their ſeparate properties; and the compounds reſulting from their union partake of the properties of thoſe ſubſtances which ſerve as their principles.

Fourthly, The ſimpler any ſubſtances are, the more perceptible and conſiderable are their Affinities: whence it follows, that the leſs bodies are compounded, the more difficult it is to analyſe them; that is, to ſeparate from each other the principles of which they conſiſt.

Fifthly, If a body conſiſt of two ſubſtances, and to this compound be preſented a third ſubſtance that has no Affinity at all with one of the two primary ſubſtances aforeſaid, but has a greater Affinity with the other than thoſe two ſubſtances have with each other, there will enſue a decompoſition, and a new union; that is, the third ſubſtance will ſeparate the two compounding ſubſtances from each other, coaleſce with that which has an Affinity with it, form therewith a new combination, and diſengage the other, which will then be left at liberty, and ſuch as it was before it had contracted any union.

Sixthly, It happens ſometimes that when a third ſubſtance is preſented to a body conſiſting of two ſubſtances, no decompoſition follows; but the two compounding ſubſtances, without quitting each other, unite with the ſubſtance preſented to them, and form a combination of three principles: and this comes to paſs when that third ſubſtance has an equal, or nearly equal, Affinity with each of the compounding ſubſtances. The ſame thing may alſo happen even when the third ſubſtance hath no Affinity but with one of the compounding ſubſtances only. To produce ſuch an effect, it is ſufficient that one of the two compounding ſubſtances have to the third body a Relation equal, or nearly equal, to that which it has to the other compounding ſubſtance with which it is already combined. Thence it follows, that two ſubſtances, which, when apart from all others, are incapable of contracting any union, may be rendered capable of incorporating together in ſome meaſure, and becoming parts of the ſame compound, by combining with a third ſubſtance with which each of them has an equal Affinity.

Seventhly, A body, which of itſelf cannot decompoſe a compound conſiſting of two ſubſtances, becauſe, as we juſt now ſaid, they have a greater Affinity with each other than it has with either of them, becomes nevertheleſs capable of ſeparating the two by uniting with one of them, when it is itſelf combined with another body having a degree of Affinity with that one ſufficient to compenſate its own want thereof. In that caſe there are two Affinities, and thence enſues a double decompoſition and a double combination.

Theſe fundamental truths, from which we ſhall deduce an explanation of all the phenomena in Chymiſtry, will be confirmed and illuſtrated by applying them, as we ſhall do, to the ſeveral caſes, of which our deſign in this Treatiſe obliges us to give a circumſtantial account.

CHAP. III.

Of Saline Subſtances in general.

IF a particle of water be intimately united with a particle of earth, the reſult will be a new compound, which, according to our third propoſition of Affinities, will partake of the properties of earth and of water; and this combination principally forms what is called a *Saline Subſtance.* Conſequently every ſaline Subſtance muſt have an affinity with earth and with water, and be capable of uniting with both or either of them, whether they be ſeparate or mixed together; and accordingly this property characteriſes all Salts or Saline Subſtances in general.

Water being volatile and Earth fixed, Salts in general are leſs volatile than the former, and leſs fixed than the latter; that is, fire, which cannot volatilize and carry off pure earth, is capable of rarefying and volatilizing a Saline Subſtance; but then this requires a greater degree of heat than is neceſſary for producing the ſame effects on pure water.

There are ſeveral ſorts of Salts, differing from one another in reſpect either of the quantity, or the quality of the earth in their compoſition; or laſtly, they differ on account of ſome additional principles, which not being combined with them in ſufficient quantity to hinder their Saline properties from appearing, permit them to retain the name of Salts, though they render them very different from the ſimpleſt Saline Subſtances.

It is eaſy to infer from what has been ſaid of Salts in general, that ſome of them muſt be more, ſome leſs, fixed or volatile than others, and ſome more, ſome leſs, diſpoſed to unite with water, with earth, or with particular ſorts of earth, according to the nature or the proportion of their principles.

Before we proceed further, it is proper juſt to mention the principal reaſons which induce us to think that every Saline Subſtance is actually a combination of earth and water, as we ſuppoſed at our entering on this ſubject. The firſt is, the conformity Salts have with earth and water, or the properties they poſſeſs in common with both. Of theſe properties we ſhall treat fully, as occaſion offers to conſider them, in examining the ſeveral ſorts of Salts. The ſecond is, that all Salts may be actually reſolved into earth and water by ſundry proceſſes; particularly by repeated diſſolution in water, evaporation, deſiccation, and calcination. Indeed the Chymiſts have not yet been able to produce a Saline Subſtance, by combining earth and water together. This favours a ſuſpicion, that beſides theſe two there is ſome other principle in the compoſition of Salts which eſcapes our reſearches, becauſe we cannot preſerve it when we decompoſe them: but it is ſufficient to our purpoſe, that water and earth are demonſtrably amongſt the real principles of Saline Subſtances, and that no experiment hath ever ſhewn us any other.

§. I. *Of* ACIDS.

OF all Saline Subſtances, the ſimpleſt is that called an *Acid*, on account of its taſte; which is like that of verjuice, ſorrel, vinegar, and other ſour things, which for the ſame reaſon are alſo called Acids. By this peculiar taſte are Acids chiefly known. They have moreover the property of turning all the blue and violet colours of vegetables red, which diſtinguiſhes them from all other ſalts.

The form under which Acids moſt commonly appear, is that of a tranſparent liquor; though ſolidity is rather their natural ſtate. This is owing to their affinity with water; which is ſo great that, when they contain but juſt as much of it as is neceſſary to conſtitute them Salts, and conſequently have a ſolid form, they rapidly unite therewith the moment they come into contact with it: and as the air is always loaded with moiſture and aqueous vapours, its contact alone is ſufficient to liquify them; becauſe they unite with its humidity, imbibe it greedily, and by that means become fluid. We therefore ſay, they attract the moiſture of the air. This change of a ſalt from a ſolid to a fluid ſtate, by the ſole contact of the air, is alſo called *Deliquium*; ſo that when a ſalt changes in this manner from a ſolid into a fluid form, it is ſaid to run *per deliquium*. Acids being the ſimpleſt ſpecies of Saline bodies, their affinities with different ſubſtances are ſtronger than thoſe of any other ſort of ſalt with the ſame ſubſtances; which is agreeable to our fourth propoſition concerning Affinities.

Acids in general have a great affinity with earths: that with which they moſt readily unite is the unvitrifiable earth to which we gave the name of abſorbent earth. They ſeem not to act at all upon vitrifiable earths, ſuch as ſand; nor yet upon ſome other kinds of earths, at leaſt while they are in their natural ſtate. Yet the nature of theſe earths may be in ſome meaſure changed, by making them red hot in the fire, and then quenching them ſuddenly in cold water: for by repeating this often they are brought nearer to the nature of abſorbent earths, and rendered capable of uniting with Acids.

When an Acid liquor is mixed with an abſorbent earth, for inſtance with chalk, theſe two ſubſtances inſtantly ruſh into union with ſo much impetuoſity, eſpecially if the Acid liquor be as much dephlegmated, or contain as little water, as may be, that a great ebullition is immediately produced, attended with conſiderable hiſſing, heat, and vapours, which riſe the very inſtant of their conjunction.

From the combination of an Acid with an abſorbent earth there ariſes a new compound, which ſome Chymiſts have called *Sal Salſum*; becauſe the Acid by uniting with the earth loſes its ſour taſte, and acquires another not unlike that of the common ſea-ſalt uſed in our kitchens; yet varying according to the different ſorts of Acids and earths combined together. The Acid at the ſame time loſes its property of turning vegetable blues and violet colours red.

If we enquire what is become of its propenſity to unite with water, we ſhall find that the earth, which of itſelf is not ſoluble in water, hath by its union with the Acid acquired a facility of diſſolving therein; ſo that our *Sal Salſum* is ſoluble in water. But, on the other hand, the Acid hath, by its union with the earth, loſt part of the affinity it had with water; ſo that if a *Sal Salſum* be dried, and freed of all ſuperfluous humidity, it will remain in that dry ſolid form, inſtead of attracting the moiſture of the air and running *per deliquium*, as the Acid would do if it were pure and unmixed with earth. However, this general rule admits of ſome exceptions; and we ſhall have occaſion in another place to take notice of certain Combinations of Acids with earths, which ſtill continue to attract the moiſture of the air, though not ſo ſtrongly as a pure Acid.

ACIDS have likewiſe a great affinity with the Phlogiſton. When we come to treat of each Acid in particular, we ſhall examine the combinations of each with the Phlogiſton: they differ ſo widely from one another, and many of them are ſo little known, that we cannot at preſent give any general idea of them.

§. II. *Of* ALKALIS.

ALKALIS are Saline combinations in which there is a greater proportion of earth than in Acids. The principal arguments that may be adduced to prove this fact are theſe: Firſt; if they be treated in the manner propoſed above for analyzing Saline Subſtances, we obtain from them a much greater quantity of earth than we do from Acids. Secondly; by combining certain Acids with certain earths we can produce Alkalis; or at leaſt ſuch ſaline compounds as greatly reſemble them. Our third and laſt argument is drawn from the properties of thoſe Alkalis which, when pure and unadulterated with any other principle, have leſs affinity with water than Acids have, and are alſo more fixed, reſiſting the utmoſt force of fire. On this account it is that they have obtained the title of *Fixed*, as well as to diſtinguiſh them from another ſpecies of Alkali, to be conſidered hereafter, which is impure and volatile.

Though fixed Alkalis, when dry, ſuſtain the utmoſt violence of fire without flying off in vapours, it is remarkable that, being boiled with water in an open veſſel, conſiderable quantities of them riſe with the ſteams: an effect which muſt be attributed to the great affinity between theſe two ſubſtances, by means whereof water communicates ſome part of its volatility to the fixed ſalt.

Alkalis freed of their ſuperfluous humidity by calcination attract the moiſture of the air, but not ſo ſtrongly as Acids: ſo that it is eaſier to procure and preſerve them in a ſolid form.

They flow in the fire, and are then capable of uniting with vitrifiable earths, and of forming therewith true glaſs; which, however, will partake of their properties, if they be uſed in ſufficient quantity.

As they melt more readily than vitrifiable earth, they facilitate its fuſion; ſo that a weaker fire will reduce it to glaſs when a fixed Alkali is joined with it, than will melt it without that addition.

Alkalis are known by their taſte, which is acrid and fiery; and by the properties they poſſeſs of turning certain vegetable blues and violet colours green; particularly ſyrop of violets.

Their affinity with Acids is greater than that of abſorbent earths; and hence it comes to paſs that if an Alkali be preſented to a combination of an Acid with an abſorbent earth, the earth will be ſeparated from the Acid by the Alkali, and a new union between the Acid and the Alkali will take place. This is both an inſtance and a proof of our fifth propoſition concerning Affinities.

If a pure Alkali be preſented to a pure Acid, they ruſh together with violence, and produce the ſame phenomena as were obſerved in the union of an abſorbent earth with an Acid; but in a greater and more remarkable degree.

Fixed Alkalis may in general be divided into two ſorts: one of theſe hath all the above recited properties; but the other poſſeſſes ſome that are peculiar to itſelf. We ſhall conſider this latter ſort more particularly under the head of Sea-Salt.

§. III. *Of* NEUTRAL SALTS.

THE Acid and the Alkali thus uniting mutually rob each other of their characteriſtic properties; ſo that the compound reſulting from their union produces no change in the blue colours of vegetables, and has a taſte which is neither ſour nor acrid, but ſaltiſh. A ſaline combination of this kind is for that reaſon named *Sal Salſum*, *Sal Medium*, or a *Neutral Salt*. Such combinations are alſo called by the plain general name of *Salts*.

It muſt be obſerved that, in order to make theſe Salts perfectly Neutral, it is neceſſary that neither of the two ſaline principles of which they are compounded be predominant over the other; for in that caſe they will have the properties of the prevailing principle. The reaſon is this: neither of theſe ſaline ſubſtances can unite with the other but in a limited proportion, beyond which there can be no further coalition between them. The action by which this perfect union is accompliſhed is termed *Saturation*; and the inſtant when ſuch proportions of the two ſaline ſubſtances are mixed together, that the one is incorporated with as much of the other as it can poſſibly take up, is called the *Point of Saturation*. All this is equally applicable to the combination of an Acid with an abſorbent earth.

The combination is known to be perfect, that is, the Point of Saturation is known to be obtained, when after repeated affuſions of an Acid in ſmall quantities to an Alkali, or an abſorbent earth, we find thoſe phenomena ceaſe, which in ſuch caſes conſtantly attend the conflict of union, as we ſaid above, namely, ebullition, hiſſing, *&c.* and we may be aſſured the Saturation is complete when the new compound hath neither an acid nor an acrid taſte, nor in the leaſt changes the blue colours of vegetables.

Neutral Salts have not ſo great an affinity with water as either Acids or Alkalis have; becauſe they are more compounded: for we obſerved before, that the affinities of the moſt compounded bodies are generally weaker than thoſe of the moſt ſimple. In conſequence hereof few Neutral Salts, when dried, attract the moiſture of the air; and thoſe that do, attract it more ſlowly and in leſs quantity than either Acids or Alkalis do.

All Neutral Salts are ſoluble in water; but more or leſs readily, and in a greater or ſmaller quantity, according to the nature of their component principles.

Water made boiling hot diſſolves a greater quantity of thoſe ſalts which do not attract the moiſture of the air, than when it is cold; and indeed it muſt be boiling hot to take up as much of them as it is capable of diſſolving: but as for thoſe which run in the air, the difference, if there be any, is imperceptible.

Some Neutral Salts have the property of ſhooting into cryſtals, and others have it not.

The nature of Cryſtallization is this: Water cannot diſſolve, nor keep in ſolution, more than a determinate quantity of any particular Salt: when therefore ſuch a quantity of water is evaporated from the ſolution of a Salt capable of cryſtallization, that the remainder contains juſt as much Salt as it can diſſolve, then by continuing the evaporation the Salt gradually recovers its ſolid form, and concretes into ſeveral little tranſparent maſſes called Cryſtals. Theſe cryſtals have regular figures, all differing from one another according to the ſpecies of Salt of which they are formed. Different methods of evaporating ſaline ſolutions have different effects on the figure and regularity of the cryſtals; and each particular ſort of Salt requires a peculiar method of evaporation to make its cryſtals perfectly regular.

A ſolution of Salt deſigned for cryſtallization is uſually evaporated by means of fire to a pellicle; that is, till the Salt begin to concrete; which is perceived by a kind of thin dark ſkin that gathers on the ſurface of the liquor, and is formed of the cryſtallized particles of Salt. When this pellicle appears the ſolution is ſuffered to cool, and the cryſtals form therein faſter or ſlower according to the ſort of Salt in hand. If the evaporation be carried on briſkly to perfect dryneſs, no cryſtals will be formed, and only an irregular maſs of Salt will be obtained.

The reaſons why no cryſtals appear when the evaporation is haſtily performed, and carried on to dryneſs, are, firſt, that the particles of Salt, being always in motion while the ſolution is hot, have not time to exert their mutual affinities, and to unite together as cryſtallization requires: ſecondly, that a certain quantity of water enters into the very compoſition of cryſtals; which is therefore abſolutely neceſſary to their formation, and in a greater or ſmaller proportion according to the nature of the Salt *.

If theſe cryſtallized Salts be expoſed to the fire, they firſt part with that moiſture which is not neceſſary to a ſaline concretion, and which they retained only by means of their cryſtallization: afterwards they begin to flow, but with different degrees of fuſibility.

It muſt be obſerved that certain Salts melt as ſoon as they are expoſed to the fire; namely, thoſe which retain a great deal of water in cryſtallizing. But this fluor which they ſo readily acquire muſt be carefully diſtinguiſhed from actual fuſion: for it is owing only to their ſuperfluous humidity, which heat renders capable of diſſolving and liquifying them; ſo that when it is evaporated the Salt ceaſes to be fluid, and requires a much greater degree of fire to bring it into real fuſion.

The Neutral Salts that do not cryſtallize may, indeed, be dried by evaporating the water which

keeps

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* Thoſe who have the curioſity to ſee a more particular account of the cryſtallization of Neutral Salts, may read Mr. *Rouelle's* excellent Memoir on that Subject, among thoſe of the Academy of Sciences for 1744.

keeps them fluid; but by becoming ſolid they acquire no regular form; they again attract the moiſture of the air, and are thereby melted into a liquor. Theſe may be called *Liqueſcent Salts.*

Moſt of the Neutral Salts, that conſiſt of an Acid joined with a fixed Alkali, or with an abſorbent earth, are themſelves fixed and reſiſt the force of fire; yet ſeveral of them, if they be diſſolved in water and the ſolution boiled and evaporated, fly off along with the ſteams.

CHAP. IV.

Of the ſeveral Sorts of Saline Subſtances.

§. I. *Of the* UNIVERSAL ACID.

THE Univerſal Acid is ſo called, becauſe it is in fact the Acid which is moſt univerſally diffuſed through all nature, in waters, in the atmoſphere, and in the bowels of the earth. But it is ſeldom pure; being almoſt always combined with ſome other ſubſtance. That from which we obtain it with moſt eaſe and in the greateſt quantity is vitriol, a mineral which we ſhall conſider afterwards: and this is the reaſon why it is called the *Vitriolic Acid*; the name by which it is beſt known.

When the Vitriolic Acid contains but little phlegm, yet enough to give it a fluid form, it is called *Oil of Vitriol*; on account of a certain unctuoſity belonging to it. In truth this name is very improperly beſtowed on it; for we ſhall afterwards ſee that, bating this unctuouſneſs, it has none of the properties of oils. But this is not the only impropriety in names we ſhall have occaſion to cenſure.

If the Vitriolic Acid contain much water it is then called *Spirit of Vitriol.* When it does not contain enough to render it fluid, and ſo is in a ſolid form, it is named the *Icy Oil of Vitriol.*

When Oil of Vitriol highly concentrated is mixed with water, they ruſh into union with ſuch impetuoſity that, the moment they touch each other, there ariſes a hiſſing noiſe, like that of red-hot iron plunged in cold water, together with a very conſiderable degree of heat proportioned to the degree in which the Acid was concentrated.

If inſtead of mixing this concentrated Acid with water, you only leave it expoſed to the air for ſome time, it attracts the moiſture thereof, and imbibes it moſt greedily. Both its bulk and its weight are increaſed by this acceſſion; and if it be under an icy form, that is, if it be concreted, the phlegm thus acquired will ſoon reſolve it into a fluid.

The addition of water renders the Vitriolic Acid, and indeed all other Acids, weaker in one ſenſe; which is, that when they are very aqueous they leave on the tongue a much fainter taſte of acidity, and are leſs active in the ſolution of ſome particular bodies: but that occaſions no change in the ſtrength of their affinities, but in ſome caſes rather enables them to diſſolve ſeveral ſubſtances, which, when well dephlegmated, they are not capable of attacking.

The Vitriolic Acid combined to the point of ſaturation with a particular abſorbent earth, the nature of which is not yet well known, forms a Neutral Salt that cryſtallizes. This Salt is called *Alum*, and the figure of its cryſtals is that of an octahedron or ſolid of eight ſides. Theſe octahedra are triangular pyramids, the angles of which are ſo cut off that four of the ſurfaces are hexagons, and the other four triangles.

There are ſeveral ſorts of Alum, which differ according to the earths combined with the Vitriolic Acid. Alum diſſolves eaſily in water, and in cryſtallization retains a conſiderable quantity of it; which is the reaſon that being expoſed to the fire it readily melts, ſwelling and puffing up as its ſuperfluous moiſture exhales. When that is quite evaporated, the remainder is called *Burnt Alum*, and is very difficult to fuſe. The Acid of the Alum is partly diſſipated by this calcination. Its taſte is ſaltiſh, with a degree of roughneſs and aſtringency.

The Vitriolic Acid combined with certain earths forms a kind of Neutral Salt called *Selenites*, which cryſtallizes in different forms according to the nature of its earth. There are numberleſs ſprings of water infected with diſſolved Selenites; but when this Salt is once cryſtallized, it is exceeding difficult to diſſolve it in water a ſecond time. For that purpoſe a very great quantity of water is neceſſary, and moreover it muſt boil; for as it cools moſt of the diſſolved Selenites takes a ſolid form, and falls in a powder to the bottom of the veſſel.

If an Alkali be preſented to the Selenites or to Alum, theſe Salts, according to the principles we have laid down, will be thereby decompoſed; that is, the Acid will quit the earths, and join the Alkali, with which it hath a greater affinity. And from this conjunction of the Vitriolic Acid with a fixed Alkali there reſults another ſort of Neutral Salt, which is called *Arcanum duplicatum*, *Sal de duobus*, and *Vitriolated Tartar*, becauſe one of the fixed Alkalis moſt in uſe is called Salt of Tartar.

Vitriolated Tartar is almoſt as hard to diſſolve in water as the Selenites. It ſhoots into eight-ſided cryſtals, having the apices of the pyramids pretty obtuſe. Its taſte is ſaltiſh, inclining to bitter; and it decrepitates on burning coals. It requires a very great degree of fire to make it flow.

The Vitriolic Acid is capable of uniting with the Phlogiſton, or rather it has a greater affinity with it than with any other body: whence it follows that all compounds, of which it makes a part, may be decompoſed by means of the Phlogiſton.

From the conjunction of the Vitriolic Acid with the Phlogiſton ariſes a compound called *Mineral Sulphur*, becauſe it is found perfectly formed in the bowels of the earth. It is alſo called *Sulphur vivum*, or ſimply, *Sulphur*.

Sulphur is abſolutely inſoluble in water, and incapable of contracting any ſort of union with it. It melts with a very moderate degree of heat, and ſublimes in fine light downy tufts called *Flowers of Sulphur*. By being thus ſublimed it ſuffers no decompoſition, let the operation be repeated ever ſo often; ſo that Sublimed Sulphur, or Flower of Sulphur, hath exactly the ſame properties as Sulphur that has never been ſublimed.

If Sulphur be expoſed to a briſk heat in the open air, it takes fire, burns, and is wholly conſumed. This deflagration of Sulphur is the only means we have of decompoſing it, in order to obtain its Acid in purity. The Phlogiſton is deſtroyed by the flame, and the Acid exhales in vapours: theſe vapours collected have all the properties of the Vitriolic Acid, and differ from it only as they ſtill retain ſome portion of the Phlogiſton; which, however, ſoon quits them of its own accord, if the free acceſs of the common air be not precluded.

The portion of Phlogiſton retained by the Acid of Sulphur is much more conſiderable when that mineral is burnt gradually and ſlowly: in that caſe the vapours which riſe from it have ſuch a penetrating odour, that they inſtantaneouſly ſuffocate any perſon who draws in a certain quantity of them with his breath. Theſe vapours conſtitute what is called the *Volatile Spirit of Sulphur*. There is reaſon to think this portion of Phlogiſton which the Acid retains is combined therewith in a manner different from that in which theſe two are united in the Sulphur itſelf; for, as has juſt been obſerved, nothing but actual burning is capable of ſeparating the Vitriolic Acid and the Phlogiſton, which by their union form Sulphur; whereas in the Volatile Spirit of Sulphur they ſeparate ſpontaneouſly when expoſed to the open air; that is, the Phlogiſton flies off and leaves the Acid, which then becomes in every reſpect ſimilar to the Vitriolic Acid.

That the Volatile Spirit of Sulphur is a compound, as we have aſſerted it to be, appears evidently from hence, that whenever the Vitriolic Acid touches any ſubſtance containing the Phlogiſton, provided that Phlogiſton be diſengaged or opened to a certain degree, a Volatile Spirit of Sulphur is infallibly and immediately generated. This Spirit hath all the properties of Acids, but conſiderably weakened, and of courſe leſs perceptible. It unites with abſorbent earths or fixed Alkalis; and with them forms Neutral Salts: but when combined therewith it may be ſeparated from them by the Vitriolic Acid, and indeed by any of the mineral Acids, becauſe its affinities are weaker. Sulphur hath the property of uniting with abſorbent earths, but not near ſo intimately as with fixed Alkalis.

If equal parts of Sulphur and an Alkali be melted together, they incorporate with each other; and from their conjunction proceeds a compound of a moſt unpleaſant ſmell, much like that of rotten eggs, and of a red colour nearly reſembling that of an animal liver, which has occaſioned it to bear the name of *Hepar Sulphuris*, or *Liver of Sulphur*.

In this compoſition the fixed Alkali communicates to the Sulphur the property of diſſolving in water: and hence it comes that Liver of Sulphur may be made as well when the Alkali is diſſolved by water into a fluid, as when it is fuſed by the action of fire.

Sulphur has leſs affinity than any Acid with the fixed Alkalis: and therefore Liver of Sulphur may be decompounded by any Acid whatever; which will unite with the fixed Alkali, form therewith a Neutral Salt, and ſeparate the Sulphur.

If Liver of Sulphur be diſſolved in water, and an Acid poured thereon, the liquor, which was tranſparent before, inſtantly turns to an opaque white; becauſe the Sulphur, being forced to quit its union with the Alkali, loſes at the ſame time the property of diſſolving in water, and appears again in its own opaque form. The liquor thus made white by the Sulphur is called *Milk of Sulphur*.

If this liquor be ſuffered to ſtand ſtill for ſome time, the particles of Sulphur, now moſt minutely divided, gradually approach each other, unite, and fall inſenſibly to the bottom of the veſſel; and then the liquor recovers its tranſparency. The Sulphur thus depoſited on the bottom of the veſſel is called the *Magiſtery* or *Precipitate of Sulphur*. The names of Magiſtery and Precipitate are alſo given to all ſubſtances whatever that are ſeparated from another by this method; which is the reaſon that we uſe the expreſſion of precipitating one ſubſtance by another, to ſignify the ſeparating one of them by means of the other.

§. II. *Of the* NITROUS ACID.

IT is not certainly known what conſtitutes the difference between the Nitrous Acid and the Vitriolic Acid, with regard to the conſtituent principles of each. The moſt probable opinion is, that the Nitrous Acid is no other than the Vitriolic Acid combined with a certain quantity of Phlogiſton by the means of putrefaction. If it be ſo, the Phlogiſton muſt be united with the Univerſal Acid in another manner than it is in ſulphur, and in its volatile ſpirit: for the Nitrous Acid differs from them both in its properties. What gives ground for this opinion is, that the Nitrous Acid is never found but in earths and ſtones which have been impregnated with matters ſubject to putrefaction, and which therefore muſt contain the Phlogiſton. For it is neceſſary juſt to obſerve here, though it be not yet proper to enter particularly into the ſubject, that all ſubſtances ſuſceptible of putrefaction really contain the Phlogiſton.

The Nitrous Acid combined with certain abſorbent earths, ſuch as chalk, marle, boles, forms Neutral Salts which do not cryſtallize; and which, after being dried, run in the air *per deliquium*.

All thoſe Neutral Salts which conſiſt of the Nitrous Acid joined to an earth, may be decompoſed by a fixed Alkali, with which the Acid unites, and deſerts the earth; and from this union of the Nitrous Acid with a fixed Alkali reſults a new Neutral Salt which is called *Nitre*, or *Salt-petre*. This latter name ſignifies the *Salt of Stone*; and in fact Nitre is extracted from the ſtones and plaiſter, in which it forms, by boiling them in water ſaturated with a fixed Alkali.

Nitre ſhoots in long cryſtals adhering ſideways to each other: it has a ſaltiſh taſte, which produces a ſenſation of cold on the tongue.

This Salt eaſily diſſolves in water; which, when it boils, takes up ſtill a greater quantity thereof.

It flows with a pretty moderate degree of heat, and continues fixed therein: but being urged by a briſk fire, and in the open air, it lets go ſome part of its Acid, and indeed flies off itſelf in part.

The moſt remarkable property of Nitre, and that which characterizes it, is its Fulmination or Exploſion; the nature of which is as follows:

When Nitre touches any ſubſtance containing a Phlogiſton, and actually ignited, that is, actually on fire, it burſts out into a flame, burns, and is decompounded with much noiſe.

In this deflagration the Acid is diſſipated, and totally ſeparated from the Alkali, which now remains by itſelf.

Indeed the Acid, at leaſt the greateſt part of it, is by this means quite deſtroyed. The Alkali which is left when Nitre is decompounded by deflagration, is called in general *Fixed Nitre*, and, more particularly, Nitre fixed by ſuch and ſuch a ſubſtance as was uſed in the operation. But if Nitre be deflagrated with an inflammable ſubſtance containing the vitriolic Acid, as ſulphur, for inſtance, the fixed Salt produced by the deflagration is not a pure Alkali, but retains a good deal of the vitriolic Acid, and, by combining therewith, hath now formed a neutral Salt.

Hitherto Chymiſts have been at a loſs for the reaſon why Nitre flames, and is decompounded in the manner above mentioned, when it comes in contact with a Phlogiſton properly circumſtanced. For my part, I conjecture it to be for the ſame reaſon that vitriolated tartar is alſo decompounded by the addition of a Phlogiſton; *viz.* the Nitrous Acid, having a greater affinity with the Phlogiſton than with the fixed Alkali, naturally quits the latter to join with the former, and ſo produces a kind of ſulphur, differing probably from the common ſulphur, formed by the vitriolic Acid, in that it is combuſtible to ſuch a degree, as to take fire and be conſumed in the very moment of its production; ſo that it is impoſſible to prevent its being thus deſtroyed, and conſequently impoſſible to ſave it. In ſupport of this opinion let it be conſidered, that the concurrence of the Phlogiſton is abſolutely neceſſary to produce this deflagration, and that the matter of pure fire is altogether incapable of effecting it: for though Nitre be expoſed to the moſt violent degree of fire, even that in the focus of the moſt powerful burning-glaſs, it will not flame; nor will that effect ever happen till the Nitre be brought into contact with a Phlogiſton properly ſo called, that is, the matter of fire exiſting as a principle of ſome body; and it is moreover neceſſary that this Phlogiſton be actually on fire, and agitated with the igneous motion, or elſe that the Nitre itſelf be red-hot, and ſo penetrated with fire as to kindle any inflammable matter that touches it.

This experiment, among others, helps to ſhew the diſtinction that ought to be made betweeen pure elementary fire, and fire become a principle of bodies to which we have given the name of Phlogiſton.

Before we leave this ſubject, we ſhall obſerve that Nitre deflagrates only with ſuch ſubſtances as contain the Phlogiſton in its ſimpleſt and pureſt form; ſuch as charcoal, ſulphur, and the metalline ſubſtances; and that, though it will not deflagrate without the addition of ſome combuſtible matter, it is nevertheleſs the only known body that will burn, and make other combuſtibles burn with it, in cloſe veſſels, without the admiſſion of freſh air.

The Nitrous Acid hath not ſo great an affinity with earths and Alkalis as the vitriolic Acid hath with the ſame ſubſtances; whence it follows that the vitriolic Acid decompoſes all neutral ſalts ariſing from a combination of the Nitrous Acid with an earth or an Alkali, The vitriolic Acid expells the Nitrous Acid, unites with the ſubſtance which ſerved it for a baſis, and therewith forms a neutral ſalt, which is an Alum, a Selenites, or a vitriolated Tartar, according to the nature of that baſis.

The Nitrous Acid, when thus ſeparated from its baſis by the vitriolic Acid, is named *Spirit of Nitre*, or *Aqua Fortis*. If it be dephlegmated, or contain but little ſuperfluous water, it exhales in reddiſh vapours; theſe vapours, being condenſed and collected, form a liquor of a browniſh yellow, that inceſſantly emits vapours of the ſame colour, and of a pungent diſagreeable ſmell. Theſe characters have procured it the names of *Smoaking Spirit of Nitre*, and *Yellow Aqua Fortis*. This property in the Nitrous Acid, of exhaling in vapours, ſhews it to be leſs fixed than the vitriolic Acid; for the latter, though ever ſo thoroughly dephlegmated, never yields any vapours, nor has it any ſmell.

§. III. *Of the* ACID OF SEA-SALT.

THE Acid of Sea-Salt is ſo called becauſe it is in fact obtained from ſuch Sea-Salt as is uſed in our kitchens. It is not certainly known in what this Acid differs from the vitriolic and the nitrous, with regard to its conſtituent parts. Several of the ableſt Chymiſts, ſuch as Becher and Stahl, are of opinion that the Marine Acid is no other than the Univerſal Acid united to a particular principle which they call a Mercurial Earth. Concerning this earth we ſhall have occaſion to ſay more when we come to treat of metallic ſubſtances: But in the mean time it muſt be owned that the truth of this opinion is ſo far from being proved by a ſufficient number of experiments, that the very exiſtence of ſuch a mercurial earth is not yet well eſtabliſhed; and therefore, that we may not exceed the bounds of our knowledge, we ſhall content ourſelves with delivering here the properties which characterize the Acid in queſtion, and by which it is diſtinguiſhed from the two others conſidered above.

When it is combined with abſorbent earths, ſuch as lime and chalk, it forms a neutral ſalt that does not cryſtallize, and, when dried, attracts the moiſture of the air. If the abſorbent earth be not fully ſaturated with the Marine Acid, the ſalt thereby formed has the properties of a fixed Alkali: and this is what made us ſay, when we were on the ſubject of thoſe ſalts, that they might be imitated by combining an earth with an Acid. The Marine Acid, like the reſt, hath not ſo great an affinity with earths as with fixed Alkalis.

When it is combined with the latter, it forms a neutral ſalt which ſhoots into cubical cryſtals. This ſalt is inclined to grow moiſt in the air, and is conſequently one of thoſe which water diſſolves in equal quantities, at leaſt as to ſenſe, whether it be boiling hot or quite cold.

The affinity of this Acid with Alkalis and abſorbent earths is not ſo great as that of the vitriolic and nitrous Acids with the ſame ſubſtances: whence it follows that, when combined therewith, it may be ſeparated from them by either of thoſe Acids.

The Acid of Sea-Salt, thus diſengaged from the ſubſtance which ſerved it for a baſis, is called *Spirit of Salt.* When it contains but little phlegm it is of a lemon colour, and continually emits many white, very denſe, and very elaſtic vapours; on which account it is named the *Smoking Spirit of Salt.* Its ſmell is not diſagreeable, nor much unlike that of ſaffron; but extremely quick and ſuffocating when it ſmokes.

The Acid of Sea-Salt, like the other two, ſeems to have a greater affinity with the Phlogiſton, than with fixed Alkalis. We are led to this opinion by a very curious operation, which gives ground to think that Sea-Salt may be decompoſed by the proper application of a ſubſtance containing the Phlogiſton.

From the Marine Acid combined with a Phlogiſton reſults a kind of Sulphur, differing from the common ſort in many reſpects; but particularly in this property, that it takes fire of itſelf upon being expoſed to the open air. This combination is called *Engliſh Phoſphorus*, *Phoſphorus of Urine*, becauſe it is generally prepared from urine, or, only *Phoſphorus.*

This combination of the Marine Acid with a Phlogiſton is not eaſily effected; becauſe it requires a difficult operation in appropriated veſſels. For theſe reaſons it does not always ſucceed; and Phoſphorus is ſo ſcarce and dear, that hitherto Chymiſts have not been able to make on it the experiments neceſſary to diſcover all its properties. If Phoſphorus be ſuffered to burn away in the air, a ſmall quantity of an acid liquor may be obtained from it, which ſeems to be ſpirit of ſalt, but either altered, or combined with ſome adventitious matter; for it has ſeveral properties that are not to be found in the pure Marine Acid; ſuch as, leaving a fixed fuſible ſubſtance behind it when expoſed to a ſtrong fire, and being eaſily combined with the Phlogiſton ſo as to reproduce a Phoſphorus.

Phoſphorus reſembles ſulphur in ſeveral of its properties: it is ſoluble in oils; it melts with a gentle heat; it is very combuſtible; it burns without producing ſoot; and its flame is vivid and bluiſh.

From what has been ſaid of the union of the Acid of Sea-Salt with a fixed Alkali, and of the neutral ſalt reſulting therefrom, it may be concluded that this neutral ſalt is no other than the common kitchen-ſalt. But it muſt be obſerved that the fixed Alkali, which is the natural baſis of the common ſalt obtained from ſea-water, is of a ſort ſomewhat differing from fixed Alkalis in general, and hath certain properties peculiar to itſelf. For,

1. The baſis of Sea-Salt differs from other fixed Alkalis in this, that it cryſtallizes like a neutral ſalt.

2. It does not grow moiſt in the air: on the contrary, when expoſed to the air, it loſes part of the water that united with it in cryſtallization, by which means its cryſtals loſe their tranſparency, become, as it were, mealy, and fall into a fine flour.

3. When combined with the vitriolic Acid to the point of ſaturation, it forms a neutral ſalt differing from vitriolated tartar, firſt, in the figure of its cryſtals, which are oblong ſix-ſided ſolids; ſecondly, in its quantity of water, which in cryſtallization unites therewith in a much greater proportion than with vitriolated tartar; whence it follows, that this ſalt diſſolves in water more readily than vitriolated tartar; thirdly, in that it flows with a very moderate degree of heat, whereas vitriolated tartar requires a very fierce one.

If the Acid of Sea-Salt be ſeparated from its baſis by means of the vitriolic Acid, it is eaſy to ſee that, when the operation is finiſhed, the ſalt we have been ſpeaking of muſt be the reſult. A famous Chymiſt, named Glauber, was the firſt who extracted the Spirit of Salt in this manner, examined the neutral ſalt reſulting from his proceſs, and, finding it to have ſome ſingular properties, called it his *Sal mirabile*, or wonderful Salt: on this account it is ſtill called Glauber's *Sal mirabile*, or plainly *Glauber's Salt*.

4. When the baſis of Sea-Salt is combined with the nitrous Acid to the point of ſaturation, there reſults a neutral ſalt, or a ſort of nitre, differing from the common nitre, firſt, in that it attracts the moiſture of the air pretty ſtrongly; and this makes it difficult to cryſtallize: ſecondly, in the figure of its cryſtals, which are parallelopipeds; and this has procured it the name of *Quadrangular Nitre*.

Common ſalt, or the neutral ſalt formed by combining the Marine Acid with this particular ſort of fixed Alkali, has a taſte well known to every body. The figure of its cryſtals is exactly cubical. It grows moiſt in the air, and, when expoſed to the fire, it burſts, before it melts, into many little fragments, with a crackling noiſe; which is called the *Decrepitation* of Sea-Salt.

That neutral ſalt mentioned above, which is formed by combining the Marine Acid with a common fixed Alkali, and called *Sal febrifugum Sylvii*, hath alſo this property.

India furniſhes us with a ſaline ſubſtance, known by the name of *Borax*, which flows very eaſily, and then takes the form of glaſs. It is of great uſe in facilitating the fuſion of metallic ſubſtances. It poſſeſſes ſome of the properties of fixed Alkalis, which has induced certain Chymiſts to repreſent it, through miſtake, as a pure fixed Alkali.

By mixing borax with the vitriolic Acid, Mr. Homberg obtained from it a ſalt, which ſublimes in a certain degree of heat, whenever ſuch a mixture is made. This ſalt has very ſingular properties; but its nature is not yet thoroughly underſtood. It diſſolves in water with great difficulty; it is not volatile, though it riſes by ſublimation from the borax. According to Mr. Rouelle's obſervation, it riſes then only by means of the water which carries it up: for when once made it abides the fierceſt fire, flows and vitrifies juſt as borax does; provided care be taken to free it previouſly from moiſture by drying it properly. Mr. Homberg called it *Sedative Salt*, on account of its medical effects. The ſedative ſalt hath the appearance, and ſome of the properties, of a neutral ſalt; for it ſhoots into cryſtals, and does not change the colour of violets: but it acts the part of an Acid with regard to Alkalis, uniting with them to the point of ſaturation, and thereby forming a true neutral ſalt. It alſo acts, like the Acid of vitriol on all neutral ſalts; that is, it diſcharges the Acid of ſuch as have not the vitriolic Acid in their compoſition.

Since Mr. Homberg's time it hath been diſcovered that a ſedative ſalt may be made either with the nitrous or with the marine Acid; and that ſublimation is not neceſſary to extract it from the borax, but that it may be obtained by cryſtallization only. For this latter diſcovery we are indebted to Mr. Geoffroy, as we are to Mr. Lemery for the former.

Since that time M. Baron d' Henouville, an able Chymiſt, hath ſhewn that a ſedative ſalt may be obtained by the means of vegetable Acids; and hath lately demonſtrated, in ſome excellent papers publiſhed in the collection of Memoirs written by the correſpondents of the Academy of Sciences, that the ſedative ſalt exiſts actually and perfectly in the borax, and that it is not produced by mixing Acids with that ſaline ſubſtance, as it ſeems all the Chymiſts before him imagined. This he proves convincingly from his analyſis of borax, (which thereby appears to be nothing elſe but the ſedative ſalt united with that fixed Alkali which is the baſis of Sea-Salt) and from his regenerating the ſame borax by uniting together that Alkali and the ſedative ſalt: a proof the moſt complete that can poſſibly be produced in natural philoſophy, and equivalent to demonſtration itſelf.

In order to finiſh what remains to be ſaid upon the ſeveral ſorts of ſaline ſubſtances, we ſhould now ſpeak of the Acids obtained from vegetables and animals, and alſo of the volatile Alkalis: but, ſeeing theſe ſaline ſubſtances differ from thoſe of which we have already treated, only as they are variouſly altered by the unions they have contracted with certain principles of vegetables and animals, of which nothing has been yet ſaid, it is proper to defer being particular concerning them, till we have explained thoſe principles.

CHAP. V.

Of LIME.

ANY ſubſtance whatever, that has been roaſted a conſiderable time in a ſtrong fire without melting, is commonly called a *Calx*. Stones and metals are the principal ſubjects that have the property of being converted into *Calces*. We ſhall treat of Metalline *Calces* in a ſubſequent chapter, and in this confine ourſelves to the *Calx* of *Stone*, known by the name of *Lime*.

In treating of earths in general we obſerved that they may be divided into two principal kinds; one of which actually and properly flows when expoſed to the action of fire, and turns to glaſs; whence it is called a *fuſible* or *vitrifiable* earth; the other reſiſts the utmoſt force of fire, and is therefore ſaid to be an *unfuſible* or *unvitrifiable* earth. The latter is alſo not uncommonly called *calcinable* earth; though ſundry ſorts of unfuſible earths are incapable of acquiring by the action of fire all the qualities of *calcined* earth, or *Lime* properly ſo called: ſuch earths are particularly diſtinguiſhed by the denomination of *refractory* earths.

As the different ſorts of ſtones are nothing more than compounds of different earths, they have the ſame properties with the earths of which they are compoſed, and may, like them, be divided into fuſible or vitrifiable, and unfuſible or calcinable. The fuſible ſtones are generally denoted by the name of *Flints*; the calcinable ſtones, again, are the ſeveral ſorts of marbles, cretaceous ſtones, thoſe commonly called free-ſtones, *&c.* ſome of which, as they make the beſt Lime, are, by way of eminence, called *Lime-ſtones.* Sea-ſhells alſo, and ſtones that abound with foſſile ſhells, are capable of being burnt to Lime.

All theſe ſubſtances, being expoſed, for a longer or ſhorter time, as the nature of each requires, to the violent action of fire, are ſaid to be *calcined.* By calcination they loſe a conſiderable part of their weight, acquire a white colour, and become friable, though ever ſo ſolid before; as, for inſtance, the very hardeſt marbles. Theſe ſubſtances, when thus calcined, take the name of *Quick Lime.*

Water penetrates Quick Lime, and ruſhes into it with vaſt activity. If a lump of newly calcined Lime be thrown into water, it inſtantly excites almoſt as great a noiſe, ebullition, and ſmoke, as would be produced by a piece of red-hot iron; with ſuch a degree of heat too, that, if the Lime be in due proportion to the water, it will ſet fire to combuſtible bodies; as hath unfortunately happened to veſſels laden with Quick Lime, on their ſpringing a ſmall leak.

As ſoon as Quick Lime is put into water, it ſwells, and falls aſunder into an infinite number of minute particles: in a word, it is in a manner diſſolved by the water, which forms therewith a ſort of white paſte called *Slacked Lime.*

If the quantity of water be conſiderable enough for the Lime to form with it a white liquor, this liquor is called *Lac Calcis*; which, being left ſome time to ſettle, grows clear and tranſparent, the Lime which was ſuſpended therein, and occaſioned its opacity, ſubſiding to the bottom of the veſſel. Then there forms on the ſurface of the liquor a cryſtalline pellicle, ſomewhat opaque and dark coloured, which being ſkimmed off is reproduced from time to time. This matter is called *Cremor Calcis.*

Slacked Lime gradually grows dry, and takes the form of a ſolid body, but full of cracks and deſtitute of firmneſs. The event is different when you mix it up, while yet a paſte, with a certain quantity of uncalcined ſtony matter, ſuch as ſand for example: then it takes the name of *Mortar*, and gradually acquires, as it grows drier and older, a hardneſs equal to that of the beſt ſtones. This is a very ſingular property of Lime, nor is it eaſy to account for it: but it is a beneficial one; for every body knows the uſe of mortar in building.

Quick Lime attracts the moiſture of the air, in the ſame manner as concentrated acids, and dry fixed alkalis; but not in ſuch quantities as to render it fluid: it only falls into extremely ſmall particles, takes the form of a fine powder, and the title of *Lime ſlacked in the air*.

Lime once ſlacked, however dry it may afterwards appear, always retains a large portion of the water it had imbibed; which cannot be ſeparated from it again but by means of a violent calcination. Being ſo recalcined it returns to be Quick Lime, recovering all its properties.

Beſides this great affinity of Quick Lime with water, which diſcovers a ſaline character, it has ſeveral other ſaline properties, to be afterwards examined, much reſembling thoſe of fixed alkalis. In Chymiſtry it acts very nearly as thoſe ſalts do, and may be conſidered as holding the middle rank between a pure abſorbent earth and a fixed alkali: and this hath induced many Chymiſts to think that Lime contains a true ſalt, to which all the properties it poſſeſſes in common with ſalts may be attributed.

But as the chymical examination of this ſubject hath long been neglected, the exiſtence of a ſaline ſubſtance in Lime hath been long doubtful. Mr. du Fay, author of ſome excellent chymical experiments, was one of the firſt who obtained a ſalt from Lime, by lixiviating it with a great deal of water, which he afterwards evaporated. But the quantity of ſalt he obtained by that means was very ſmall; nor was it of an alkaline nature, as one would think it ſhould have been, conſidering the properties of Lime. Mr. du Fay did not carry his experiments on this ſubject any further, probably for want of time; nor did he determine of what nature the ſalt was.

Mr. Malouin had the curioſity to examine this ſalt of Lime, and ſoon found that it was nothing elſe but what was above called *Cremor Calcis.* He found moreover, that, by mixing a fixed alkali with Lime-water, a vitriolated tartar was formed; that, by mixing therewith an alkali like the baſis of ſea ſalt, a Glauber's ſalt was produced; and laſtly, by combining Lime with a ſubſtance abounding in phlogiſton he obtained a true ſulphur. Theſe very ingenious experiments prove to a demonſtration that the vitriolic acid conſtitutes the ſalt of Lime: for, as hath been ſhewn, no other acid is capable of forming ſuch combinations. On the other hand, Mr. Malouin, having forced the vitriolic acid of this ſalt to combine with a phlogiſton, found its baſis to be earthy, and analogous to that of the ſelenites: whence he concluded that the ſalt of Lime is a true neutral ſalt, of the ſame kind as the ſelenites. Mr. Malouin tells us he found ſeveral other ſalts in Lime. But as none of them was a fixed alkali, and as all the ſaline properties of Lime have an affinity with thoſe of that kind of ſalt, there is great reaſon to think that all thoſe ſalts are foreign to Lime, and that their union with it is merely accidental.

I myſelf have made ſeveral experiments in order to get ſome inſight into the ſaline nature of Lime, and ſhall here produce the reſult with all poſſible conciſeneſs. I took ſeveral ſtones of different kinds, ſome of which produced by calcination a very ſtrong Lime, and others but a very weak one. Theſe I impregnated with different ſaline ſubſtances, acids, alkalis and neutrals, and then expoſed them all to the ſame degree of fire, which was a pretty ſtrong one, and long enough continued to have made very good Lime of ſtones the moſt difficult to calcine. The conſequence was, that, in the firſt place, thoſe ſtones which naturally made but a weak Lime were not by this proceſs converted into a ſtronger Lime; and, moreover, that none of theſe ſtones, even ſuch as would naturally have produced the moſt active Lime, had acquired the properties of Lime. Theſe experiments I varied many ways, employing different proportions of ſaline matters, and almoſt every poſſible degree of fire, and conſtantly obſerved, after calcination, that all thoſe ſtones were ſo much the further from the nature of Lime, as they had been combined with larger doſes of ſalts. Among thoſe which were impregnated with the greateſt proportion of ſalts, and had ſuffered the greateſt violence of fire, I obſerved ſome that had begun to flow, and were in a manner vitrified. Now as the ſame ſubject cannot be, at one and the ſame time, in the ſtate of glaſs and of Lime too; as a body cannot approach to one of theſe ſtates but in proportion as it recedes from the other; and as ſalts in general diſpoſe thoſe bodies to fuſion and vitrification which are in themſelves the moſt averſe to either, I concluded from my experiments, that the ſaline ſubſtances I uſed had, by acting as fluxes upon the ſtones, prevented their calcination; that conſequently we may ſuſpect there is no ſaline matter in the compoſition of Lime, as Lime; and that Lime does not owe its ſaline and alkaline properties to any ſalt; or at leaſt that if it does owe thoſe properties to a ſalt, ſuch ſalt muſt be naturally and originally combined with the matter of the ſtone in ſo juſt a proportion, that it is impoſſible to increaſe the quantity thereof without prejudicing the Lime, and depriving it in ſome meaſure of its virtue. This theory agrees perfectly with the illuſtrious Stahl's opinion; for he thinks, as we obſerved in diſcourſing of Salts in general, that every ſaline ſubſtance is but an earth combined in a certain manner with water. This notion he applies to Lime, and ſays that fire only ſubtilizes and attenuates the earthy matter, and thereby renders it capable of uniting with water in ſuch a manner, that the reſult of their combination ſhall be a ſubſtance having ſaline properties; and that Lime accordingly never acquires theſe properties till it be combined with water.

I have dwelt longer on the Salt of Lime than I ſhall on any other particular; becauſe the ſubject, though in itſelf of great importance, has hitherto been but little attended to, and becauſe the experiments here recited are entirely new.

Lime unites with all acids, and in conjunction with them exhibits various phenomena.

The vitriolic acid poured upon Lime diſſolves it with efferveſcence and heat. From this mixture there exhales a great quantity of vapours, in ſmell and colour perfectly like thoſe of ſea-ſalt; from which however they are found to be very different when collected into a liquor. From this combination of the vitriolic acid with Lime ariſes a neutral ſalt, which ſhoots into cryſtals, and is of the ſame kind with the ſelenitic ſalt obtained from Lime by Mr. Malouin.

The nitrous acid poured upon Lime diſſolves it in like manner with efferveſcence and heat: but the ſolution is tranſparent, and therein differs from the former, which is opaque. From this mixture there ariſes a neutral ſalt, which does not cryſtallize, and has withal the very ſingular property of being volatile, and riſing wholly by diſtillation in a liquid form. This phenomenon is ſo much the more remarkable, as Lime, the baſis of this ſalt, is one of the moſt fixed bodies known in Chymiſtry.

With the acid of ſea-ſalt Lime forms alſo a ſingular ſort of ſalt, which greedily imbibes the moiſture of the air. We ſhall have occaſion to take further notice of it in another place.

Theſe experiments made on Lime with acids are likewiſe quite new. We are indebted for them to Mr. Du Hamel of the Academy of Sciences, whoſe admirable Memoirs on ſeveral ſubjects ſhew his extenſive knowledge in all parts of Natural Philoſophy.

Lime applied to fixed alkalis adds conſiderably to their cauſtic quality, and makes them more penetrating and active. An alkaline lixivium in which Lime hath been boiled, being evaporated to dryneſs, forms a very cauſtic ſubſtance, which flows in the fire much more eaſily, attracts and retains moiſture much more ſtrongly, than fixed alkalis that have not been ſo treated. An alkali thus acuated by Lime is called the *Cauſtic Stone*, or *Potential Cautery*; becauſe it is employed by ſurgeons to produce eſchars on the ſkin and cauterize it.

CHAP. VI.

Of Metallic Subſtances in general.

METALLIC Subſtances are heavy, glittering, opaque, fuſible bodies. They conſiſt chiefly of a vitrifiable earth united with the phlogiſton.

Several Chymiſts inſiſt on a third principle in theſe bodies, and have given it the name of *Mercurial earth*; which, according to Becher and Stahl, is the very ſame that being combined with the vitriolic acid forms and characterizes the acid of ſea ſalt. The exiſtence of this principle hath not yet been demonſtrated by any deciſive experiment; but we ſhall ſhew that there are pretty ſtrong reaſons for admitting it.

We ſhall begin with mentioning the experiments which prove Metallic Subſtances to conſiſt of a vitrifiable earth united with the phlogiſton. The firſt is this: if they be calcined in ſuch a manner as to have no communication with any inflammable matter, they will be ſpoiled of all their properties, and reduced to an earth or calx, that has neither the ſplendour nor the ductility of a metal, and in a ſtrong fire turns to an actual glaſs, inſtead of flowing like a metal.

The ſecond is, that the calx or the glaſs reſulting from a metal thus decompoſed, recovers all its metalline properties by being fuſed in immediate contact with an inflammable ſubſtance, capable of reſtoring the phlogiſton of which calcination had deprived it.

On this occaſion we muſt obſerve that Chymiſts have not yet been able, by adding the Phlogiſton, to give the properties of metals to all ſorts of vitrifiable earths indiſcriminately; but to ſuch only as originally made a part of ſome metallic body. For example, a compound cannot be made with the phlogiſton and ſand that ſhall have the leaſt reſemblance of a metal: and this is what ſeems to point out the reality of a third principle, as neceſſary to form the metalline combination. This principle may probably remain united with the vitrifiable earth of a metallic ſubſtance, when reduced to a glaſs; whence it follows, that ſuch vitrified metals require only the addition of a phlogiſton to enable them to appear again in their priſtine form.

It may be inferred from another experiment, that the calx and the glaſs of a metal are not its pure vitrifiable earth, properly ſo called: for by repeated or long continued calcinations, ſuch a calx or glaſs may be rendered incapable of ever reſuming the metalline form, in whatever manner the phlogiſton be afterwards applied to it; ſo that by this means it is brought into the condition of a pure vitrifiable earth, abſolutely free from any mixture. Thoſe Chymiſts who patroniſe the Mercurial earth, produce many other proofs of the exiſtence of that principle in metallic ſubſtances; but they would be miſplaced in an elementary treatiſe like this.

When by adding the phlogiſton to a metallic glaſs we reſtore it to the form of a metal, we are ſaid to *reduce*, *reſuſcitate*, or *revivify* that metal.

Metallic ſubſtances are of different kinds, and are divided into *Metals* and *Semi-metals*.

Thoſe are called Metals which, beſides their metalline ſplendour and appearance, are alſo malleable; that is, have the property of ſtretching under the hammer, and by that means of being wrought into different forms without breaking.

Thoſe which have only the metalline ſplendour and appearance, without malleability, are called Semi-metals.

Metals alſo are further ſubdivided into two ſorts; *viz.* *Perfect* and *Imperfect* Metals.

The Perfect Metals are thoſe which ſuffer no damage or change whatever by the moſt violent and moſt laſting action of fire.

The Imperfect Metals are thoſe which by the force of fire may be deprived of their phlogiſton, and conſequently of their metalline form.

When a moderate degree of fire only is employed to deprive a Metal of its phlogiſton, the metal is ſaid to be *calcined*; and then it appears in the form of a powdered earth, which is called a *Calx*: and this metalline calx being expoſed to a more violent degree of fire melts and turns to glaſs.

Metallic Subſtances have an affinity with acids; but not equally with all; that is, every Metallic Subſtance is not capable of uniting and joining with every acid.

When an acid unites with a Metallic Subſtance there commonly ariſes an ebullition, attended with a kind of hiſſing noiſe and fuming exhalations. By degrees, as the union becomes more perfect, the particles of the metal combining with the acid become inviſible: this is termed *Diſſolution*; and when a metalline maſs thus diſappears in an acid, the metal is ſaid to be *diſſolved* by that acid. It is proper to obſerve that acids act upon metalline ſubſtances, in one reſpect, juſt as they do upon alkalis and abſorbent earths: for an acid cannot take up above ſuch a certain proportion thereof as is ſufficient to ſaturate it, to deſtroy ſeveral of its properties, and weaken others. For example, when an acid is combined with a metal to the point of ſaturation, it loſes its taſte, does not turn the blue colour of a vegetable red, and its affinity with water is conſiderably impaired. On the other hand, Metalline Subſtances, which when pure are incapable of uniting with water, by being joined with an acid acquire the property of diſſolving in water. Theſe combinations of Metalline Subſtances with acids form different ſorts of neutral ſalts; ſome of which have the property of ſhooting into cryſtals, while others have it not: moſt of them, when thoroughly dried, attract the moiſture of the air.

The affinity which Metalline Subſtances have with acids is leſs than that which abſorbent earths and fixed alkalis have with the ſame acids: ſo that all metalline ſalts may be decompounded by one of theſe ſubſtances, which will unite with the acid, and precipitate the metal.

Metalline Subſtances thus ſeparated from an acid ſolvent are called *Magiſteries*, and *Precipitates*, of metals. None of theſe precipitates, except thoſe of the perfect metals, retain the metalline form: moſt of their phlogiſton hath been deſtroyed by the ſolution and precipitation, and muſt be reſtored before they can recover their properties. In ſhort, they are nearly in the ſame ſtate with metalline ſubſtances deprived of their phlogiſton by calcination; and accordingly ſuch a precipitate is called a *Calx*.

A metalline calx prepared in this manner loſes a greater or a leſs portion of its phlogiſton, the more or leſs effectually and thoroughly the metalline ſubſtance, of which it made a part, was diſſolved by the acid.

Metallic Subſtances have affinities with each other which differ according to their different kinds: but this is not univerſal; for ſome of them are incapable of any ſort of union with ſome others.

It muſt be obſerved that Metallic Subſtances will not unite, except they be both in a ſimilar ſtate; that is, both in a Metalline form, or both in the form of a Glaſs; for a metalline ſubſtance retaining its phlogiſton cannot contract an union with any metallic glaſs, even its own.

CHAP. VIII.

Of METALS.

THERE are ſix Metals, of which two are Perfect and four Imperfect. The perfect Metals are Gold and Silver; the others are Copper, Tin, Lead, and Iron. Some Chymiſts admit a ſeventh Metal, to wit, Quick-ſilver: but as it is not malleable, it has been generally conſidered as a metallic body of a particular kind. We ſhall ſoon have occaſion to examine it more minutely.

The ancient Chymiſts, or rather the Alchymiſts, who fancied a certain relation or analogy between Metals and the Heavenly Bodies, beſtowed on the ſeven Metals, reckoning Quick-ſilver one of them, the names of the ſeven Planets of the Ancients, according to the affinity which they imagined they obſerved between thoſe ſeveral bodies. Thus Gold was called *Sol*, Silver *Luna*, Copper *Venus*, Tin *Jupiter*, Lead *Saturn*, Iron *Mars*, and Quick-ſilver *Mercury*. Though theſe names were aſſigned for reaſons merely chimerical, yet they ſtill keep their ground; ſo that it is not uncommon to find the Metals called by the names, and denoted by the characters, of the Planets, in the writings even of the beſt Chymiſts. Metals are the heavieſt bodies known in nature.

§. I. Of GOLD.

GOLD is the heavieſt of all Metals. The arts of wire-drawing and gold-beating ſhew its wonderful ductility. The greateſt violence of fire is not able to produce any alteration in it. Indeed Mr. Homberg, a famous Chymiſt, pretended that he had made this metal fume, and even vitrified it, by expoſing it to the focus of one of the beſt burning glaſſes, known by the name of the Lens of the *Palais Royal:* but there are very good reaſons for calling in queſtion the experiments he made on this occaſion, or rather for thinking that he was quite miſtaken. For,

1. No man hath ſince been able to vitrify Gold, though ſeveral good Experimenters have aſſiduouſly tried to effect it, by expoſing it to the focus of the ſame lens, and of other burning-glaſſes ſtill ſtronger.

2. It hath been obſerved that though Gold, when expoſed to the focus of thoſe glaſſes, did indeed emit ſome vapours and decreaſe in weight; yet thoſe vapours being carefully collected on a piece of paper, proved to be true Gold, in no degree vitrified, and which conſequently had ſuffered no change but that of being carried away by the violence of the heat, its nature not being in the leaſt altered.

3. The ſmall portion of vitrified matter, which was formed on the arm that ſupported the Gold in Mr. Homberg's experiment, may have come either from the arm itſelf, or rather from ſome heterogeneous particles contained in the Gold; for it is almoſt impoſſible to have it perfectly pure.

4. Neither Mr. Homberg, nor any that have repeated his experiment, ever reduced this pretended glaſs of Gold by reſtoring its phlogiſton, as is done with other metallic glaſſes.

5. To render the experiment deciſive, the whole maſs of Gold employed ought to have been vitrified; which was not the caſe.

Nevertheleſs I do not pretend that this metal is in its own nature abſolutely indeſtructible, and unvitrifiable:

vitrifiable: but there is reaſon to think that no body hath hitherto found the means of producing thoſe effects on it, probably for want of a ſufficient degree of fire; at leaſt the point is very doubtful.

Gold cannot be diſſolved by any pure acid: but if the acid of nitre be mixed with the acid of ſea-ſalt, there reſults a compound acid liquor, with which it has ſo great an affinity that it is capable of being perfectly diſſolved thereby. The Chymiſts have called this ſolvent *Aqua Regis*, on account of its being the only acid that can diſſolve Gold, which they conſider as the King of Metals. The ſolution of Gold is of a beautiful orange colour.

If Gold diſſolved in *aqua regis* be precipitated by an alkali or an abſorbent earth, the precipitate gently dried, and then expoſed to a certain degree of heat, is inſtantly diſperſed into the air, with a moſt violent exploſion and noiſe: Gold thus precipitated is therefore called *Aurum Fulminans*. But if the precipitated Gold be carefully waſhed in plenty of water, ſo as to clear it of all the adhering ſaline particles, it will not fulminate; but may be melted in a crucible without any additament, and will then appear in its uſual form. The acid of vitriol being poured on *aurum fulminans* likewiſe deprives it of its fulminating quality.

Gold does not begin to flow till it be red-hot like a live coal. Though it be the moſt malleable and moſt ductile of all metals, it has the ſingular property of loſing its ductility more eaſily than any of them: even the fumes of charcoal are ſufficient to deprive it thereof, if they come in contact with it while it is in fuſion.

The malleability of this metal, and indeed of all the reſt, is alſo conſiderably diminiſhed by expoſing it ſuddenly to cold when it is red-hot; for

example,

example, by quenching it in water, or even barely expoſing it to the cold air.

The way to reſtore ductility to Gold, when loſt by its coming in contact with the vapour of coals, and in general to every other metal rendered leſs malleable by being ſuddenly cooled, is to heat them again, to keep them red-hot a conſiderable time, and then to let them cool very ſlowly and gradually: this operation frequently repeated will by degrees much increaſe the malleability of a metal.

Pure ſulphur hath no effect on Gold; but being combined with an alkali into a *hepar ſulphuris*, it unites therewith very readily. Nay, ſo intimate is their union, that the Gold by means thereof becomes ſoluble in water; and this new compound of Gold and liver of ſulphur, being diſſolved in water, will paſs through the pores of brown paper without ſuffering any decompoſition; which does not happen, at leaſt in ſuch a manifeſt degree, to other metallic ſubſtances diſſolved by liver of ſulphur.

Aurum fulminans mixed and melted with flower of ſulphur loſes its fulminating quality: which ariſes from hence, that on this occaſion the ſulphur burns, and its acid, which is the ſame with the vitriolic, being thereby ſet at liberty becomes capable of acting upon the Gold as a vitriolic acid would; which, as was ſaid above, deprives the Gold of its fulminating quality.

§. II. *Of* SILVER.

NEXT to Gold Silver is the moſt perfect metal. Like Gold it reſiſts the utmoſt violence of fire, even that in the focus of a burning-glaſs. However it holds only the ſecond place among metals; becauſe it is lighter than Gold by almoſt one half; is alſo ſomewhat leſs ductile; and laſtly, becauſe it is acted upon by a greater number of ſolvents.

Yet Silver hath one advantage over Gold, namely that of being a little harder; which makes it alſo more ſonorous.

This metal, like Gold, begins to flow when it is ſo thoroughly penetrated by the fire as to appear ignited like a live coal.

While this metal is in fuſion, the immediate contact of the vapour of burning coals deprives it almoſt entirely of its malleability, in the ſame manner as we obſerved happens to Gold: but both theſe metals eaſily recover that property by being melted with nitre.

The nitrous acid is the true ſolvent of Silver, and being ſomewhat dephlegmated will very readily and eaſily take up a quantity of Silver equal in weight to itſelf.

Silver thus combined with the nitrous acid forms a metallic ſalt which ſhoots into cryſtals, called by the name of *Lunar Cryſtals*, or *Cryſtals of Silver*.

Theſe cryſtals are moſt violently cauſtic: applied to the ſkin they quickly affect it much as a live coal would; they produce a blackiſh eſchar, corroding and entirely deſtroying the parts they touch. Surgeons uſe them to eat away the proud fungous fleſh of ulcers. As Silver united with the nitrous acid hath the property of blackening all animal ſubſtances, a ſolution of this metallic ſalt is employed to die hair, or other animal matters, of a beautiful and durable black.

Theſe cryſtals flow with a very moderate heat, and even before they grow red. Being thus melted they form a blackiſh maſs; and in this form they are uſed by Surgeons, under the title of *Lapis infernalis*, *Infernal Stone*, or *Silver Cauſtic*.

Silver is alſo diſſolved by the vitriolic acid: but then the acid muſt be concentrated, and in quantity double the weight of the Silver; nor will the ſolution ſucceed without a conſiderable degree of heat.

Spirit of ſalt and *aqua regis*, as well as the other acids, are incapable of diſſolving this metal; at leaſt in the ordinary way.

Though Silver be not ſoluble in the acid of ſea-ſalt, nor eaſily in the acid of vitriol, as hath juſt been obſerved, it doth not follow that it hath but a weak affinity with the latter, and none at all with the former: on the contrary, it appears from experiment that it hath with theſe two acids a much greater affinity than with the acid of nitre: which is ſingular enough, conſidering the facility with which this laſt acid diſſolves it.

The experiment which proves the fact is this. To a ſolution of Silver in the nitrous acid add the acid either of vitriol or of ſea-ſalt, and the Silver will inſtantly quit its nitrous ſolvent to join with the ſuperadded acid.

Silver thus united with the vitriolic or the marine acid is leſs ſoluble in water than when combined with the nitrous acid: and for this reaſon it is, that when either of theſe two acids is added to a ſolution of Silver, the liquor immediately becomes white, and a precipitate is formed, which is no other than the Silver united with the precipitating acid. If the precipitation be effected by the vitriolic acid, the precipitate will diſappear upon adding a ſufficient quantity of water, becauſe there will then be water enough to diſſolve it. But the caſe is not the ſame when the precipitation is made by the marine acid: for Silver combined therewith is ſcarce ſoluble in water.

This Precipitate of Silver procured by means of the marine acid is very eaſily fuſed, and when fuſed changes to a ſubſtance in ſome meaſure tranſparent and flexible; which hath occaſioned it to be called by the name of *Luna Cornea.* If it be propoſed to decompound this *luna cornea*, that is, to ſeparate the marine acid from the Silver with which it is united, the *luna cornea* muſt be melted along with fatty and abſorbent matters, with which the acid will unite, and leave the metal exceeding pure.

It muſt be obſerved that if, inſtead of the marine acid, ſea-ſalt in ſubſtance be added to a ſolution of Silver in the nitrous acid, a Precipitate is alſo produced, which by fuſion appears to be a true *luna cornea*. The reaſon is, that the ſea-ſalt is decompoſed by the nitrous acid, which ſeizes its baſis, as having a greater affinity therewith than its own acid hath; and this acid being conſequently diſengaged and ſet at liberty unites with the Silver, which, as has been ſhewn, has a greater affinity with it than with the nitrous acid. This is an inſtance of decompoſition effected by means of one of thoſe double affinities mentioned by us in our ſeventh propoſition concerning Affinities.

From what hath been already ſaid it is clear, that all theſe combinations of Silver with acids may be decompounded by abſorbent earths and by fixed alkalis; it being a general law with regard to all metallic ſubſtances. We ſhall not therefore repeat this obſervation when we come to treat of the other metals; unleſs ſome particular occaſion require it.

With regard to Silver I muſt take notice that, when ſeparated by theſe means from the acids in which it was diſſolved, it requires nothing but ſimple fuſion to reſtore it to its uſual form; becauſe it does not, any more than Gold, loſe its phlogiſton by thoſe ſolutions and precipitations.

Silver unites with ſulphur in fuſion. If this metal be only made red-hot in a crucible, and ſulphur be then added, it immediately flows; the ſulphur acting as a flux to it. Silver thus united with ſulphur forms a maſs that may be cut, is half malleable, and hath nearly the colour and conſiſtence of Lead. If this ſulphurated Silver be kept a long time in fuſion, and in a great degree of heat, the ſulphur flies off and leaves the Silver pure. But if the ſulphur be evaporated by a violent heat, it carries off with it part of the Silver.

Silver unites and mixes perfectly with Gold in fuſion. The two metals thus mixed form a compound with properties partaking of both.

Metallurgiſts have hitherto ſought in vain for a perfectly good and eaſy method of ſeparating theſe two metals by the *dry way* only: (this term is uſed to ſignify all operations performed by fuſion:) but they are conveniently enough parted by the *moiſt way*, that is, by acid ſolvents. This method is founded on the above-mentioned properties of Gold and Silver with reſpect to acids. It hath been ſhewn that *aqua regis* only will diſſolve Gold; that Silver, on the contrary, is not ſoluble by *aqua regis*, and that its proper ſolvent is the acid of nitre: conſequently, when Gold and Silver are mixed together, if the compound maſs be put into *aqua fortis*, this acid will take up all the Silver, without diſſolving a particle of the Gold, which will therefore remain pure; and by this means the deſired ſeparation is effected. This method, which is commonly made uſe of by Goldſmiths and in Mints, is called the *Parting Aſſay*.

It is plain that if *aqua regis* were employed inſtead of *aqua fortis*, the ſeparation would be equally effected; and that the only difference between this proceſs and the former would conſiſt in this, that now the Gold would be diſſolved, and the Silver remain pure. But the operation by *aqua fortis* is preferable; becauſe *aqua regis* does take up a little Silver, whereas *aqua fortis* hath not the leaſt effect on Gold.

It muſt be obſerved that when Gold and Silver are mixed together in equal parts they cannot be parted by the means of *aqua fortis*. To enable the *aqua fortis* to act duly on the Silver, this metal muſt be, at leaſt, in a triple proportion to the Gold. If it be in a leſs proportion, you muſt either employ *aqua regis* to make the ſeparation, or, if you prefer the uſe of *aqua fortis*, melt the metalline maſs, and add as much Silver as is neceſſary to make up the proportion above-mentioned: and hence this Proceſs is called *Quartation.*

This effect, which is pretty ſingular, probably ariſes from hence, that when the Gold exceeds or even equals the Silver in quantity, the parts of both being intimately united, the former are capable of coating over the latter, and covering them ſo as to defend them from the action of the *aqua fortis*; which is not the caſe when there is thrice as much Silver as Gold.

There is one thing more to be taken notice of with regard to this proceſs; which is, that perfectly pure *aqua fortis* is rarely to be met with, for two reaſons; firſt, it is difficult in making it wholly to prevent the riſing of the medium employed to diſengage the nitrous acid; that is, a little of the vitriolic acid will mix with the vapours of the *aqua fortis*: ſecondly, unleſs the ſaltpetre be very well purified it will always hold ſome ſmall portion of ſea-ſalt, the acid of which, we know, is very readily ſet looſe by the vitriolic acid, and conſequently riſes together with the vapours of the *aqua fortis.* It is eaſy to ſee that *aqua fortis* mixed either with the one or the other is not proper for the Parting Proceſs; becauſe, as has juſt been ſaid, the vitriolic and the marine acid equally precipitate Silver diſſolved in the nitrous acid; by which means, when they are united with that acid they weaken its action upon the Silver, and hinder the diſſolution. Add that *aqua fortis* adulterated with a mixture of ſpirit of ſalt becomes an *aqua regis*, and conſequently is rendered capable of diſſolving Gold, in proportion as its action upon Silver is diminiſhed.

In order to remedy this inconvenience, and free *aqua fortis* from the vitriolic or marine acid with which it is tainted, Silver muſt be diſſolved therein: by degrees as the metal diſſolves, thoſe heterogeneous acids lay hold of it, and precipitate with it in the form of a white powder, as we obſerved before. This precipitate being wholly fallen, the liquor grows clear; after which, if it be found capable of diſſolving more Silver, without turning milky, it may be depended on as a perfectly pure *aqua fortis*. Then filtre it, diſſolve more Silver in it, as long as it will take up any, and you will have a ſolution of Silver in a very pure *aqua fortis*. By means of this ſolution may other *aqua fortis* be purified: for pour a few drops thereof into a very impure *aqua fortis*, and immediately the vitriolic or marine acid, with which that *aqua fortis* is contaminated, will join the Silver and fall therewith to the bottom. When the ſolution of Silver prepared as above does not in the leaſt affect the tranſparency of the *aqua fortis*, it is then very pure, and fit for the purpoſes of Quartation.

This operation of purifying *aqua fortis* by a ſolution of Silver is called the *Precipitation* of *aqua fortis*; and *aqua fortis* thus purified is called *Precipitated Aqua Fortis*.

When Silver is diſſolved in *aqua fortis* it may be ſeparated therefrom, as hath been ſhewn, by abſorbent earths and fixed alkalis.

We ſhall ſee by and by that there are other means of effecting this: but whatever way it be ſeparated from its ſolvent it recovers its metalline form, as Gold does, by being ſimply fuſed without any additament.

§. III. Of COPPER.

OF all the imperfect metals Copper comes the neareſt to Gold and Silver. Its natural colour is a deep-red yellow. It reſiſts a very violent degree of fire for a conſiderable time; but loſing its phlogiſton at laſt, it changes its metalline form for that of a calx, or a pure reddiſh earth. This calx is hardly, if at all, reducible to glaſs, without the addition of ſomething to promote its fuſion; all that the fierceſt heat can do being only to render it ſoft. Copper, even while it retains its metalline form, and is very pure, requires a conſiderable degree of fire to melt it, and does not begin to flow till long after it is red-hot. When in fuſion, it communicates a greeniſh colour to the flame of the coals.

This metal is inferiour to Silver in point of gravity; nor is its ductility ſo great, tho' it be pretty conſiderable: but, on the other hand, it exceeds that metal in hardneſs. It unites readily with Gold and Silver; nor does it greatly leſſen their beauty when added to them in a ſmall quantity: nay, it even procures them ſome advantages; ſuch as making them harder, and leſs ſubject to loſe their ductility, of which thoſe metals are often liable to be deprived, by the mixture of the ſmalleſt heterogeneous particle. This may probably ariſe from hence, that the ductility of Copper has the peculiarity of reſiſting moſt of thoſe cauſes which rob the perfect metals of theirs.

The property, which other metalline ſubſtances have in common with Copper, of loſing the phlogiſton by calcining and then vitrifying, furniſhes us with a method of ſeparating them from Gold and Silver, when they are combined therewith. Nothing more is required than to expoſe the maſs compounded of the perfect metals and other metalline ſubſtances to a de-a degree of heat ſufficient to calcine whatever is not either Gold or Silver. It is evident that by this means theſe two metals will be obtained as pure as is poſſible; for, as hath already been ſaid, no metalline calx or glaſs is capable of uniting with metals poſſeſſed of their phlogiſton. On this prinple is formed the whole buſineſs of refining Gold and Silver.

When the perfect metals have no other alloy but Copper, as this metal is not to be calcined or vitrified without great difficulty, which is increaſed by its union with the unvitrifiable metals, it is eaſy to ſee that it is almoſt impoſſible to ſeparate them without adding ſomething to facilitate the vitrification of the Copper. Such metals as have the property of turning eaſily to glaſs are very fit for this purpoſe; and it is neceſſary to add a certain quantity thereof, when Gold or Silver is to be purified from the alloy of Copper. We ſhall have occaſion to be more particular on this ſubject when we come to treat of Lead.

Copper is ſoluble in all the acids, to which it communicates a green colour, and ſometimes a blue. Even the neutral ſalts, and water itſelf, act upon this metal. With regard to water indeed, as the procuring it abſolutely pure and free from any ſaline mixture is next to an impoſſibility, it remains a queſtion whether the effect it produces on Copper be not owing to certain ſaline particles contained in it. It is this great facility of being diſſolved that renders Copper ſo ſubject to ruſt; which is nothing elſe but ſome parts of its ſurface corroded by ſaline particles contained in the ſurrounding air and water.

The ruſt of Copper is always green or blue, or of a colour between theſe two. Internally uſed it is very noxious, being a real poiſon, as are all the ſolutions of this metal made by any acid whatever.

The blue colour, which Copper conſtantly aſſumes when corroded by any ſaline ſubſtance, is a ſure ſign by which it may be diſcovered wherever it exiſts, even in a very ſmall quantity.

Copper diſſolved in the vitriolic acid forms a kind of metalline ſalt, which ſhoots into rhomboidal cryſtals of a moſt beautiful blue colour. Theſe cryſtals are called *Blue Vitriol*, or *Vitriol of Copper*. They are ſometimes found ready formed in the bowels of the earth; and may be artificially made by diſſolving Copper in the vitriolic acid; but the ſolution will not ſucceed unleſs the acid be well dephlegmated. The taſte of this vitriol is ſaltiſh and aſtringent. It retains a conſiderable quantity of water in cryſtallizing, on which account it is eaſily rendered fluid by fire.

It muſt be obſerved that, when it is expoſed to a certain degree of heat in order to free it of its humidity, a great part of its acid flies off at the ſame time: and hence it is that, after calcination, there remains only a kind of earth, or metalline calx, of a red colour, which contains but very little acid. This earth cannot be brought to flow but with the greateſt difficulty.

A ſolution of Copper in the nitrous acid forms a ſalt which does not cryſtallize, but, when dried, powerfully attracts the moiſture of the air. The ſame thing happens when it is diſſolved in ſpirit of ſalt, or in *aqua regis*.

If the Copper thus diſſolved by any of theſe acids be precipitated by an earth or an alkali, it retains nearly the colour it had in the ſolution: but theſe precipitates are ſcarce any thing more than the earth of Copper, or Copper deprived of moſt of its phlogiſton; ſo that if they were expoſed to a violent fire, without any additament, a great part of them would be converted into an earth that could never be reduced to a metalline form. Therefore, when we intend to reduce theſe precipitates to Copper, it is neceſſary to add a certain quantity of a ſubſtance capable of reſtoring to them the phlogiſton they have loſt.

The ſubſtance which hath been found fitteſt for ſuch reductions is charcoal-duſt; becauſe charcoal is nothing but a phlogiſton cloſely combined with an earth, which renders it exceedingly fixed, and capable of reſiſting a violent force of fire. But as charcoal will not melt, and conſequently is capable of preventing rather than forwarding the flux of a metalline calx or glaſs, which nevertheleſs is eſſentially neceſſary to complete the reduction, it hath been contrived to mix it, or any other ſubſtance containing the phlogiſton, with ſuch fixed alkalis as eaſily flow, and are fit to promote the flux of other bodies. Theſe mixtures are called *Reducing Fluxes*; becauſe the general name of *Fluxes* is given to all ſalts, or mixtures of ſalts, which facilitate fuſion.

If Sulphur be applied to Copper made perfectly red-hot, the metal immediately runs; and theſe two ſubſtances uniting form a new compound much more fuſible than pure Copper.

This compound is deſtroyed by the ſole force of fire, for two reaſons: the firſt is, that, ſulphur being volatile, the fire is capable of ſubliming a great part of it, eſpecially when it is in a great proportion to the Copper with which it is joined; the ſecond is, that the portion of ſulphur which remains, being more intimately united with the Copper, though it be rendered leſs combuſtible by that union, is nevertheleſs burnt and conſumed in time. Copper being combined with ſulphur, and together with it expoſed to the force of fire, is found to be partly changed into a blue vitriol; becauſe the vitriolic acid, being diſengaged by burning the ſulphur, is by that means qualified to diſſolve the Copper.

The affinity of Copper with ſulphur is greater than that of Silver.

This metal, as well as the other imperfect metals and the ſemi-metals, being mingled with nitre and expoſed to the fire, is decompoſed and calcined much ſooner than by itſelf; becauſe the phlogiſton which it contains occaſions the deflagration of the nitre, and conſequently the two ſubſtances mutually decompoſe each other. There are certain metalline ſubſtances whoſe phlogiſton is ſo abundant, and ſo weakly connected with their earth, that, when they are thus treated with nitre, there ariſes immediately a detonation, accompanied with flame, and as violent as if ſulphur or charcoal-duſt had been employed; ſo that in a moment the metalline ſubſtance loſes its phlogiſton, and is calcined. The nitre, after theſe detonations, always aſſumes an alkaline character.

§. IV. *Of* IRON.

IRON is lighter and leſs ductile than Copper; but it is much harder, and of more difficult fuſion.

It is the only body that has the property of being attracted by the magnet, which therefore ſerves to diſcover it wherever it is. But it muſt be obſerved that it hath this property only when in its metalline ſtate, and loſes it when converted to an earth or calx. Hence very few Iron-ores are attracted by the loadſtone; becauſe, for the moſt part, they are only ſorts of earths, which require a phlogiſton to be added before they can be brought to the form of true Iron.

When Iron hath undergone no other preparation but the fuſion which is neceſſary to ſmelt it from its ore, it is uſually quite brittle, and flies to pieces under the hammer: which ariſes in ſome meaſure from its containing a certain portion of unmetallic earth interpoſed between its parts. This we call *Pig Iron.*

By melting this a ſecond time it is rendered purer, and more free from heterogeneous matters: but ſtill, as its proper parts are probably not brought ſufficiently near, or cloſely enough united, till the Iron hath undergone ſome further preparation beſides that of fuſion, it ſeldom hath any degree of malleability.

The way to give it this property is to make it juſt red-hot, and then hammer it for ſome time in all directions; to the end that its parts may be properly united, incorporated, and welded together, and that the heterogeneous matters which keep them aſunder may be ſeparated. Iron made by this means as malleable as poſſible we call *Bar Iron*, or *Forged Iron.*

Bar Iron is ſtill harder to fuſe than Pig Iron: to make it flow requires the utmoſt force of fire.

Iron has the property of imbibing a greater quantity of phlogiſton than is neceſſary to give it the metalline form. It may be made to take in this ſuperabundant phlogiſton two ways: the firſt is by fuſing it again with matters that contain the phlogiſton; the ſecond is, by encompaſſing it with a quantity of ſuch matters, charcoal-duſt for inſtance, and then expoſing it ſo encompaſſed, for a certain time, to a degree of fire barely ſufficient to keep it red-hot. This ſecond method, whereby one ſubſtance is incorporated with another by means of fire, but without fuſing either of them, is in general called *Cementation.*

Iron thus impregnated with an additional quantity of phlogiſton is called *Steel.* The hardneſs of Steel may be conſiderably augmented by *tempering* it; that is, by making it red-hot, and ſuddenly quenching it in ſome cold liquor. The hotter the metal, and the colder the liquor in which it is quenched, the harder will the Steel be. By this means tools are made, ſuch as files and ſheers, capable of cutting and dividing the hardeſt bodies, as glaſs, pebbles, and Iron itſelf. The colour of Steel is darker than that of Iron, and the facets which appear on breaking it are ſmaller. It is alſo leſs ductile and more brittle, eſpecially when tempered.

As Iron may be impregnated with an additional quantity of phlogiſton, and thereby converted into Steel, ſo may Steel be again deprived of that ſuperabundant phlogiſton, and brought back to the condition of Iron. This is effected by cementing it with poor earths, ſuch as calcined bones and chalk. By the ſame operation Steel may be *untempered:* nay, it will loſe the hardneſs it had acquired by tempering, if it be but made red-hot, and left to cool gradually. As Iron and Steel differ only in the reſpects we have here taken notice of, their properties being in all other reſpects the ſame, what follows is equally applicable to both.

Iron being expoſed to the action of fire for ſome time, eſpecially when divided into ſmall particles, ſuch as filings, is calcined and loſes its phlogiſton. By this means it turns to a kind of reddiſh yellow earth, which on account of its colour is called *Crocus Martis*, or *Saffron of Mars.*

This calx of Iron has the ſingular property of flowing in the fire with ſomewhat leſs difficulty than Iron itſelf; whereas every other metalline calx flows with leſs eaſe than the metal that produced it. It has moreover the remarkable property of uniting with the phlogiſton, and of being reduced to Iron without fuſion; requiring for that purpoſe only to be made red-hot.

Iron may be incorporated with Silver, and even with Gold, by means of certain operations. Under the article of Lead we ſhall ſee how it may be ſeparated from theſe metals.

The acids produce on it much the ſame effects as on Copper: every one of them acts upon it. Certain neutral ſalts, alkalis, and even water itſelf, are capable of diſſolving it; and hence it is alſo very ſubject to ruſt. The vitriolic acid diſſolves it with the greateſt eaſe: but the circumſtances which attend the diſſolution thereof are different from thoſe with which the ſame acid diſſolves Copper: for 1. whereas the vitriolic acid muſt be concentrated to diſſolve Copper, it muſt on the contrary be diluted with water to diſſolve Iron, which it will not touch when well dephlegmated. 2. The vapours which riſe in this diſſolution are inflammable; ſo that if it be made in a ſmall-necked bottle, and the flame of a candle be applied to the mouth thereof, the vapours in the bottle take fire with ſuch rapidity as to produce a conſiderable exploſion.

This ſolution is of a beautiful green colour; and from this union of the vitriolic acid with Iron there reſults a neutral metalline ſalt, which has the property of ſhooting into cryſtals of a rhomboidal figure, and a green colour. Theſe cryſtals are called *Green Vitriol*, and *Vitriol of Mars*.

Green Vitriol hath a ſaltiſh and aſtringent taſte. As it retains a great deal of water in cryſtallizing it quickly flows by the action of fire: but this fluidity is owing to its water only, and is not a real fuſion; for as ſoon as its moiſture is evaporated, it reſumes a ſolid form. Its green tranſparent colour is now changed into an opaque white: and, if the calcination be continued, its acid alſo exhales and is diſſipated in vapours; and as it loſes that, it turns gradually to a yellow colour, which comes ſo much the nearer to a red the longer the calcination is continued, or the higher the force of the fire is raiſed; which being driven to the utmoſt, what remains is of a very deep red. This remainder is nothing but the body of the Iron, which having loſt its phlogiſton is now no more than an earth, nearly of the ſame nature with that which is left after calcining the metal itſelf.

Green Vitriol diſſolved in water ſpontaneouſly lets fall a yellowiſh earthy ſediment. If this ſolution be defecated by filtration, it ſtill continues to depoſite ſome of the ſame ſubſtance, till the vitriol be wholly decompoſed. This ſediment is nothing but the earth of Iron, which is then called *Ochre.*

The nitrous acid diſſolves Iron with great eaſe. This ſolution is of a yellow colour, inclining more or leſs to a ruſſet, or dark-brown, as it is more or leſs ſaturated with Iron. Iron diſſolved by this acid alſo, falls ſpontaneouſly in a kind of calx, which is incapable of being diſſolved a ſecond time; for the nitrous acid will not act upon Iron that has loſt its phlogiſton. This ſolution does not cryſtallize, and if evaporated to dryneſs attracts the moiſture of the air.

Spirit of ſalt likewiſe diſſolves Iron, and this ſolution is green. The vapours which riſe during the diſſolution are inflammable, like thoſe which aſcend when this metal is attacked by the vitriolic acid. *Aquà regis* makes a ſolution of Iron, which is of a yellow colour.

Iron hath a greater affinity than either Silver or Copper with the nitrous and vitriolic acids: ſo that if Iron be preſented to a ſolution of either in one of theſe two acids, the diſſolved metal will be precipitated; becauſe the acid quits it for the Iron, with which it has a greater affinity.

On this occaſion it muſt be obſerved that if a ſolution of Copper in the vitriolic acid be precipitated by means of Iron, the precipitate has the form and ſplendour of a metal, and does not require the addition of a phlogiſton to reduce it to true Copper;

which is not the caſe, as has been ſhewn, when the precipitation is effected by earths or alkaline ſalts.

The colour of this metalline precipitate hath deceived ſeveral perſons, who being unacquainted with ſuch phenomena, and with the nature of blue vitriol, imagined that Iron was tranſmuted into Copper, when they ſaw a bit of Iron laid in a ſolution of that vitriol become, in form and external appearance, exactly like Copper: whereas the ſurface only of the Iron was cruſted over with the particles of Copper contained in the vitriol, which had gradually fallen upon and adhered to the Iron, as they were precipitated out of the ſolution.

Among the ſolvents of Iron we mentioned fixed alkalis; and that they have ſuch a power is proved by the following phenomenon. If a large proportion of alkaline ſalts be ſuddenly mixed with a ſolution of Iron in an acid, no precipitation enſues, and the liquor remains clear and pellucid; or if at firſt it look a little turbid, that appearance laſts but a moment, and the liquor preſently recovers its tranſparency. The reaſon is, that the quantity of alkali is more than ſufficient to ſaturate all the acid of the ſolution, and the ſuperabundant portion thereof, meeting with the Iron already finely divided by the acid, diſſolves it with eaſe as faſt as it falls, and ſo prevents its muddying the liquor. To evince that this is ſo in fact, let the alkali be applied in a quantity that is not ſufficient, or but barely ſufficient, to ſaturate the acid, and the Iron will then precipitate like any other metal.

Water alſo acts upon Iron; and therefore Iron expoſed to moiſture grows ruſty. If Iron-filings be expoſed to the dew, they turn wholly to a ruſt, which is called *Crocus Martis Aperiens*.

Iron expoſed to the fire together with nitre makes it detonate pretty briſkly, ſets it in a flame, and decompoſes it with rapidity.

This metal hath a greater affinity than any other metalline ſubſtance with ſulphur; on which account it is ſucceſsfully uſed to precipitate and ſeparate all metalline ſubſtances combined with ſulphur.

Sulphur uniting with Iron communicates to it ſuch a degree of fuſibility, that if a maſs of this metal heated red-hot be rubbed with a bit of ſulphur, it inceſſantly runs into as perfect a fuſion as a metal expoſed to the focus of a large burning-glaſs.

§. V. Of TIN.

TIN is the lighteſt of all metals. Though it yields eaſily to the impreſſion of hard bodies, it has but little ductility. Being bent backwards and forwards it makes a ſmall crackling noiſe. It flows with a very moderate degree of fire, and long before it comes to be red-hot. When it is in fuſion, its ſurface ſoon grows duſky, and there forms upon it a thin dark-coloured duſty pellicle, which is no other than a part of the Tin that has loſt its phlogiſton, or a calx of Tin. The metal thus calcined eaſily recovers its metalline form on the addition of a phlogiſton. If the calx of Tin be urged by a ſtrong fire it grows white, but the greateſt violence of heat will not fuſe it; which makes ſome Chymiſts conſider it as a calcinable or abſorbent earth, rather than a vitrifiable one. Yet it turns to glaſs in ſome ſort when mixed with any other ſubſtance that vitrifies eaſily. However, it always produces an imperfect glaſs only, which is not at all tranſparent, but of an opaque white. The calx of Tin thus vitrified is called *Enamel.* Enamels are made of ſeveral colours by the addition of this or that metalline calx.

Tin unites eaſily with all the metals; but it deſtroys the ductility and malleability of every one of them, Lead excepted. Nay, it poſſeſſes this property of making metals brittle in ſuch an eminent degree, that the very vapour of it, when in fuſion, is capable of producing this effect. Moreover, which is very ſingular, the moſt ductile metals, even Gold and Silver, are thoſe on which it works this change with the moſt eaſe and in the greateſt degree. It has alſo the property of making Silver mixed with it flow over a very ſmall fire.

It adheres to, and in ſome meaſure incorporates with, the ſurface of Copper and of Iron; whence aroſe the practice of coating over thoſe metals with Tin. Tin-Plates are no other than thin plates of Iron tinned over.

If to twenty parts of Tin one part of Copper be added, this alloy renders it much more ſolid, and the mixed maſs continues tolerably ductile.

If on the contrary to one part of Tin ten parts of Copper be added. together with a little Zink, a ſemi-metal to be conſidered hereafter, from this combination there reſults a metalline compound which is hard, brittle, and very ſonorous; ſo that it is uſed for caſting bells: this compoſition is called *Bronze* and *Bell-metal.*

Tin hath an affinity with the vitriolic, nitrous, and marine acids. All of them attack and corrode it; yet none of them is able to diſſolve it without great difficulty: ſo that if a clear ſolution thereof be deſired, particular methods muſt be employed for that purpoſe; for the acids do but in a manner calcine it, and convert it to a kind of white calx or precipitate, The ſolvent which has the greateſt power over it is *aqua regis*, which has even a greater affinity therewith than with Gold itſelf; whence it follows that Gold diſſolved in *aqua regis* may be precipitated by means of Tin; but then the *aqua regis* muſt be weakened. Gold thus precipitated by Tin is of a moſt beautiful colour, and is uſed for a red in enameling and painting on porcelain, as alſo to give a red colour to artificial gems. If the *aqua regis* be not lowered, the precipitate will not have the purple colour.

Tin hath the property of giving a great luſtre to all red colours in general; on which account it is uſed by the dyers for ſtriking a beautiful ſcarlet, and tin veſſels are employed in making fine ſyrup of violets. Water does not act upon this metal, as it does upon Iron and Copper; for which reaſon it is not ſubject to ruſt: nevertheleſs when it is expoſed to the air its ſurface ſoon loſes its poliſh and ſplendour.

Tin mixed with nitre and expoſed to the fire deflagrates with it, makes it detonate, and is immediately converted to a *refractory calx:* for ſo all ſubſtances are called which are incapable of fuſion.

Tin readily unites with ſulphur, and with it becomes a brittle and friable maſs.

§. VI. *Of* LEAD.

NEXT to Gold and Mercury Lead is the heavieſt of all metalline ſubſtances, but in hardneſs is exceeded by every one of them. Of all metals alſo it melts the eaſieſt, except Tin. While it is in fuſion there gathers inceſſantly on its ſurface, as on that of Tin, a blackiſh, duſty pellicle, which is nothing but a calx of Lead.

This calx further calcined by a moderate fire, the flame being reverberated on it, ſoon grows white. If the calcination be continued it becomes yellow, and at laſt of a beautiful red. In this ſtate it is called *Minium*, and is uſed as a pigment. *Minium* is not eaſily made, and the operation ſucceeds well in large manufactures only.

To convert Lead into *Litharge*, which is the metal in a manner half vitrified, you need only keep it melted by a pretty ſtrong fire; for then as its ſurface gradually calcines, it tends more and more to fuſion and vitrification.

All theſe preparations of Lead are greatly diſpoſed to perfect fuſion and vitrification, and for that purpoſe require but a moderate degree of fire; the calx or earth of Lead being of all metalline earths that which vitrifies the moſt eaſily.

Lead hath not only the property of turning into glaſs with the greateſt facility, but it hath alſo that of promoting greatly the vitrification of all the other imperfect metals; and, when it is actually vitrified, procures the ready fuſion of all earths and ſtones in general, even thoſe which are refractory, that is, which could not be fuſed without its help.

Glaſs of Lead, beſides its great fuſibility, hath alſo the ſingular property of being ſo ſubtile and active as to corrode and penetrate the crucibles in which it is melted, unleſs they be of an earth that is exceeding hard, compact, and withal very refractory: for Glaſs of Lead, being one of the moſt powerful fluxes that we know, if the earth of the crucible in which it is melted be in the ſmalleſt degree fuſible, it will be immediately vitrified; eſpecially if there be any metallic matter in its compoſition.

The great activity of Glaſs of Lead may be weakened by joining it with other vitrifiable matters: but unleſs theſe be added in a very great proportion, it will ſtill remain powerful enough to penetrate common earths, and carry off the matters combined with it.

On theſe properties of Lead, and of the Glaſs of Lead, depends the whole buſineſs of refining Gold and Silver. It hath been ſhewn that as theſe two metals are indeſtructible by fire, and the only ones which have that advantage, they may be ſeparated from the imperfect metals, when mixed therewith, by expoſing the compound to a degree of fire ſufficiently ſtrong to vitrify the latter; which when once converted into glaſs can no longer remain united with any metal that has its metalline form. But it is very difficult to procure this vitrification of the imperfect metals, when united with Gold and Silver; nay, it is in a manner impoſſible to vitrify them entirely, for two reaſons: firſt, becauſe moſt of them are naturally very difficult to vitrify; ſecondly, becauſe the union they have contracted with the perfect metals defends them, in a manner, from the action of the fire, and that ſo much the more effectually as the proportion of the perfect metals is greater; which being indeſtructible, and in ſome ſort coating over thoſe with which they are alloyed, ſerve them as a preſervative and impenetrable ſhield againſt the utmoſt violence of fire.

It is therefore clear that a great deal of labour may be ſaved, and that Gold and Silver may be refined to a much greater degree of purity than can otherwiſe be obtained, if to a mixture of theſe metals with Copper, for inſtance, or any other imperfect metal, be added a certain quantity of Lead. For the Lead, by its known property, will infallibly produce the deſired vitrification; and as it likewiſe increaſes the proportion of the imperfect metals, and ſo leſſens that of the perfect metals, in the maſs, it evidently deprives the former of a part of their guard, and ſo effects a more complete vitrification. In concluſion, as the Glaſs of Lead hath the property of running through the crucible, and carrying with it the matters which it has vitrified, it follows that when the vitrification of the imperfect metals is effected by its means, all thoſe vitrified matters together penetrate the veſſel containing the fuſed metalline maſs, diſappear, and leave only the Gold and Silver perfectly pure, and freed, as far as is poſſible, from all admixture of heterogeneous parts.

The better to promote the ſeparation of ſuch parts it is uſual to employ in this proceſs a particular ſort of ſmall crucibles, made of the aſhes of calcined bones, which are exceedingly porous and eaſily pervaded. They are called *cupels*, on account of their figure, which is that of a wide-mouthed cup: and from hence the operation takes its name; for when we refine Gold and Silver in this manner we are ſaid to *cupel* thoſe metals. It is eaſy to perceive that the more Lead is added the more accurately will the Gold and Silver be refined; and that ſo much the more Lead ought to be added as the perfect metals are alloyed with a greater proportion of the imperfect. This is the moſt ſevere trial to which a perfect metal can be put, and conſequently any metal that ſtands it may be fairly conſidered as ſuch.

In order to denote the fineneſs of Gold, it is ſuppoſed to be divided into twenty-four parts called *carats*; and Gold which is quite pure and free from all alloy is ſaid to be twenty-four *carats fine*; that which contains $\frac{1}{24}$ part of alloy is called Gold of twenty-three carats; that which contains $\frac{2}{24}$ of alloy is but twenty-two carats; and ſo on. Silver again is ſuppoſed to be divided into twelve parts only, which are called *penny-weights*: ſo that when abſolutely pure it is ſaid to be twelve *penny-weights fine*; when it contains $\frac{1}{12}$ of alloy, it is then called eleven penny-weights fine; when it contains $\frac{2}{12}$ of alloy, it is called ten penny-weights fine, and ſo on.

In treating of Copper we promiſed to ſhew under the article of Lead how to ſeparate it from Iron. The proceſs is founded on that property of Lead which renders it incapable of mixing and uniting with Iron, though it readily diſſolves all other metalline ſubſtances. Therefore if you have a maſs compounded of Copper and Iron, it muſt be fuſed with a certain quantity of Lead, and then the Copper, h ater affinity with Lead than with Iror he latter and join the former, wh ible of any union with Iron, as was ſaid, will wholly exclude it from the new compound. The next point is to ſeparate the Lead from the Copper; which is done by expoſing the maſs compounded of theſe two metals to a degree of fire ſtrong enough to deprive the Lead of its metalline form, but too weak to have the ſame effect on the Copper: and this may be done; ſince of all the imperfect metals Lead is, next to Tin, the eaſieſt to be calcined, and Copper on the contrary reſiſts the greateſt force of fire longeſt, without loſing its metalline form. Now what we gain by this exchange, viz. by ſeparating Copper from Iron and uniting it with Lead, conſiſts in this, that as Lead is calcined with leſs fire than Iron, the Copper is leſs expoſed to be deſtroyed: For it muſt be obſerved that, however moderate the fire be, it is hardly poſſible to prevent a certain quantity thereof from being calcined in the operation.

Lead melted with a third part of Tin forms a compound, which being expoſed to a fire capable of making it thoroughly red-hot, ſwells, puffs up, ſeems in ſome ſort to take fire, and is preſently calcined. Theſe two metals mixed together are much ſooner calcined than either of them ſeparately.

Both Lead and Tin are in ſome meaſure affected by water, and by a moiſt air; but they are both much leſs ſubject than Iron or Copper to be corroded by theſe ſolvents, and of courſe are much leſs leſs liable to ruſt.

The vitriolic acid acts upon and diſſolves Lead much in the ſame manner as it doth Silver.

The nitrous acid diſſolves this metal with much eaſe and in great quantities; and from this ſolution a ſmall portion of mercury may be obtained. On this ſubject ſee our *Elements of the Practice of Chymiſtry*.

When this ſolution of Lead is diluted with a good deal of water, the Lead precipitates in the form of a white powder; which happens becauſe the acid is rendered too weak to keep the Lead diſſolved.

If this ſolution of Lead be evaporated to a certain degree, it ſhoots into cryſtals formed like regular pyramids with ſquare baſes. Theſe cryſtals are of a yellowiſh colour and of a ſaccharine taſte: they do not eaſily diſſolve in water. This nitrous metalline ſalt has the ſingular property of detonating in a crucible, without any additament, or the contact of any other inflammable ſubſtance. This property it derives from the great quantity of phlogiſton contained in and but looſely connected with the Lead which is one of its principles.

If ſpirit of ſalt, or even ſea-ſalt in ſubſtance, be added to a ſolution of Lead in the nitrous acid, a white precipitate immediately falls; which is no other than the Lead united with the marine acid. This precipitate is extremely like the precipitate of Silver made in the ſame manner, and that being called *Luna cornea* hath occaſioned this to be named *Plumbum corneum*. Like the *luna cornea* it is very fuſible, and being melted hardens like it into a kind of horny ſubſtance: it is volatile, and may be reduced by means of inflammable matters combined with alkalis. But it differs from the *luna cornea* in this chiefly, that it diſſolves eaſily in water; whereas the *luna cornea*, on the contrary, diſſolves therein with great difficulty, and in a very ſmall quantity.

As this precipitation of Lead from its ſolution in ſpirit of nitre is procured by the marine acid, Lead is thereby proved to have a greater affinity with the latter acid than with the former. Yet, if you attempt to diſſolve Lead directly by the acid of ſea-ſalt, the ſolution is not ſo eaſily effected as by the ſpirit of nitre, and it is always imperfect; for it wants one of the conditions eſſential to every ſolution in a liquor, namely tranſparency.

If Lead be boiled for a long time in a lixivium of fixed alkali, part of it will be diſſolved.

Sulphur renders this metal refractory and ſcarce fuſible; and the maſs they form when united together is friable. Hence it appears that ſulphur acts upon Lead much in the ſame manner as upon Tin; that is, it renders both theſe metals leſs fuſible, which are naturally the moſt fuſible of any, while it exceedingly facilitates the fuſion of Silver, Copper, and Iron, metals which of themſelves flow with the greateſt difficulty.

CHAP. IX.

Of QUICK-SILVER.

WE treat of Quick-ſilver in a chapter apart, becauſe this metallic ſubſtance cannot be claſſed with the metals properly ſo called, and yet has ſome properties which will not allow us to confound it with the ſemi-metals. The reaſon why Quick-ſilver, by the Chymiſts commonly called Mercury, is not reputed a metal is, that it wants one of the eſſential properties thereof, to wit, malleability. When it is pure and unadulterated with any mixture, it is always fluid, and of courſe unmalleable. But as, on the other hand, it eminently poſſeſſes the opacity, the ſplendour, and above all the gravity of a metal, being next to Gold the heavieſt of all bodies, it may be conſidered as a true metal, differing from the reſt no otherwiſe than by being conſtantly in fuſion; which we may ſuppoſe ariſes from its aptneſs to flow with ſuch a ſmall degree of heat, that be there ever ſo little warmth on earth, there is ſtill more than enough to keep Mercury in fuſion; which would become ſolid and malleable if it were poſſible to apply to it a degree of cold conſiderable enough for that purpoſe. Theſe properties will not allow us to confound it with the ſemi-metals: Add that we are not yet aſſured by any undoubted experiment that it can be wholly deprived of its phlogiſton, as the imperfect metals may. Indeed we cannot apply the force of fire to it as could be wiſhed: for it is ſo volatile that it flies off and exhales in vapours with a much leſs degree of fire than is neceſſary to make it red-hot. The vapours of Mercury thus raiſed by the action of fire, being collected and united in a certain quantity, appear to be no other than true Mercury, retaining every one of its properties; and no experiment hath ever been able to ſhew the leaſt change thus produced in its nature.

If Mercury be expoſed to the greateſt heat that it can bear without ſublimation, and continued in it for ſeveral months, or even a whole year together, it turns to a red powder, which the Chymiſts call *Mercurius præcipitatus per ſe*. But to ſuceed in this operation it is abſolutely neceſſary that the heat be ſuch as is above-ſpecified; for this metallic ſubſtance may remain expoſed to a weaker heat for a conſiderable number of years, without undergoing any ſenſible alteration.

Some Chymiſts fancied that by this operation they had fixed Mercury and changed its nature; but without any reaſon: for if the Mercury thus ſeemingly tranſmuted be expoſed to a ſomewhat ſtronger degree of fire, it ſublimes and exhales in vapours as uſual; and thoſe vapours collected are nothing elſe but running Mercury, which has recovered all its properties without the help of any additament.

Mercury has the property of diſſolving all the metals, Iron only excepted. But it is a condition abſolutely neceſſary to the ſucceſs of ſuch diſſolution, that the metalline ſubſtances be poſſeſſed of their phlogiſton; for if they be calcined, Mercury cannot touch them: and hence it follows that Mercury doth not unite with ſubſtances that are purely earthy. Such a combination of a metal with Mercury is called an *Amalgam.* Trituration alone is ſufficient to effect it; however, a proper degree of heat alſo is of uſe.

Mercury amalgamated with a metal gives it a conſiſtence more or leſs ſoft, and even fluid, according to the greater or ſmaller proportion of Mercury employed. All amalgams are ſoftened by heat, and hardened by cold.

Mercury is very volatile; vaſtly more ſo than the moſt unfixed metals: moreover the union it contracts with any metal is not ſufficiently intimate to entitle the new compound reſulting from that union to all the properties of the two ſubſtances united; at leaſt with regard to their degree of fixity and volatility. From all which it follows that the beſt and ſureſt method of ſeparating it from metals diſſolved by it, is to expoſe the amalgam to a degree of heat ſufficient to make all the Quick-ſilver riſe and evaporate; after which the metal remains in the form of a powder, and being fuſed recovers its malleability. If it be thought proper to ſave the Quick-ſilver, the operation muſt be performed in cloſe veſſels, which will confine and collect the mercurial vapours. This operation is moſt frequently employed to ſeparate Gold and Silver from the ſeveral ſorts of earths and ſands with which they are mixed in the ore; becauſe theſe two metals, Gold eſpecially, are of ſufficient value to compenſate the loſs of Mercury, which is inevitable in this proceſs: beſides, as they very readily amalgamate with it, this way of ſeparating them from every thing unmetallic is very facile and commodious.

Mercury is diſſolved by acids; but with circumſtances peculiar to each particular ſort of acid.

The vitriolic acid concentrated and made boiling hot ſeizes on it, and preſently reduces it to a kind of white powder, which turns yellow by the affuſion of water, but does not diſſolve in it: it is called *Turbith Mineral.* However, the vitriolic acid on this occaſion unites with a great part of the Mercury in ſuch a manner that the compound is ſoluble in water. For if to the water which was uſed to waſh the Turbith a fixed alkali be added, there falls inſtantly a ruſſet-coloured precipitate, which is no other than Mercury ſeparated from the vitriolic acid by the intervention of the alkali.

This diſſolution of Mercury by the vitriolic acid is accompanied with a very remarkable phenomenon; which is, that the acid contracts a ſtrong ſmell of volatile ſpirit of ſulphur: a notable proof that part of the phlogiſton of the Mercury hath united therewith. And yet, if the Mercury be ſeparated by means of a fixed alkali, it does not appear to have ſuffered any alteration. Turbith mineral is not ſo volatile as pure Mercury.

The nitrous acid diſſolves Mercury with eaſe. The ſolution is limpid and tranſparent, and as it grows cold ſhoots into cryſtals, which are a nitrous mercurial ſalt.

If this ſolution be evaporated to dryneſs, the Mercury remains impregnated with a little of the acid, under the form of a red powder, which hath obtained the names of *Red Precipitate*, and *Arcanum Corallinum.* This Precipitate, as well as Turbith, is leſs volatile than pure Mercury.

If this ſolution of Mercury be mixed with a ſolution of Copper made likewiſe in the nitrous acid, and the mixture evaporated to dryneſs, there will remain a green powder called *Green Precipitate.*

Theſe precipitates are cauſtic and corroſive; and are uſed as ſuch in ſurgery.

Though Mercury be diſſolved more eaſily and completely by the nitrous acid than by the vitriolic, yet it has a greater affinity with the latter than with the former: for if a vitriolic acid be poured into a ſolution of Mercury in ſpirit of nitre, the Mercury will quit the latter acid in which it was diſſolved, and join the other which was added. The ſame thing happens when the marine acid is employed inſtead of the vitriolic.

Mercury combined with ſpirit of ſalt forms a ſingular body; a metalline ſalt which ſhoots into long cryſtals, pointed like daggers. This ſalt is volatile, and ſublimes eaſily without decompoſition. It is moreover the moſt violent of all the corroſives hitherto diſcovered by Chymiſtry. It is called *Corroſive Sublimate*, becauſe it muſt abſolutely be ſublimed to make the combination perfect. There are ſeveral ways of doing this: but the operation will never fail if the Mercury be rarified into vapours and meet with the marine acid in a ſimilar ſtate.

Corroſive Sublimate is diſſolved by water, but in very ſmall quantities only. It is decompounded by fixed alkalis, which precipitate the Mercury in a reddiſh yellow powder, called on account of its colour *Yellow Precipitate.*

If Corroſive Sublimate be mixed with tin, and the compound diſtilled, a liquor comes over which continually emits abundance of denſe fumes, and from the name of its inventor is called the *Smokeing Liquor of Libavius.* This liquor is no other than the tin combined with the marine acid of the Corroſive Sublimate, which therefore it hath actually decompounded: whence it follows that this acid hath a greater affinity with tin than with Mercury.

The marine acid in Corroſive Sublimate is not quite ſaturated with Mercury; but is capable of taking up a much greater quantity thereof. For if Corroſive Sublimate be mixed with freſh Mercury, and ſublimed a ſecond time, another compound will be produced containing much more Mercury, and leſs acrimonious; for which reaſon it is named *Sweet Sublimate of Mercury*, *Mercurius dulcis*, *Aquila alba*. This compound may be taken internally, and is purgative or emetic according to the doſe adminiſtered. It may be rendered ſtill more gentle by repeated ſublimations, and then it takes the title of *Panacæa Mercurialis*. No way hath hitherto been found to diſſolve Mercury in *aqua regis* without great difficulty, and even then it is but imperfectly diſſolved.

Mercury unites eaſily and intimately with ſulphur. If theſe two ſubſtances be only rubbed together in a gentle heat, or even without any heat, they will contract an union, though but an incomplete one. This combination takes the form of a black powder, which has procured it the name of *Æthiops mineral*.

If a more intimate and perfect union be deſired, this compound muſt be expoſed to a ſtronger heat; and then a red ponderous ſubſtance will be ſublimed, appearing like a maſs of ſhining needles: this is the combination deſired, and is called *Cinabar*. In this form chiefly is Mercury found in the bowels of the earth. Cinabar finely levigated acquires a much brighter red colour, and is known to painters by the name of *Vermilion*.

Cinabar riſes wholly by ſublimation, without ſuffering any decompoſition; becauſe the two ſubſtances of which it conſiſts, viz. Mercury and ſulphur, are both volatile.

Though Mercury unites and combines very well with ſulphur, as hath been ſaid, yet it hath leſs affinity with that mineral than any other metal, Gold only excepted: whence it follows that any of the other metals will decompound Cinabar, by uniting with its ſulphur; and ſo ſetting the Mercury at liberty to appear in its uſual form. Mercury thus ſeparated from ſulphur is eſteemed the pureſt, and bears the name of *Mercury revivified from Cinabar.*

Iron is generally uſed in this operation preferably to the other metals, becauſe among them all it has the greateſt affinity with ſulphur, and is the only one that has none with Mercury.

Cinabar may alſo be decompounded by means of fixed alkalis; the affinity of theſe ſalts with ſulphur being generally greater than that of any metalline ſubſtance whatever.

CHAP. IX.

Of the SEMI-METALS.

§. I. *Of* REGULUS OF ANTIMONY.

REGULUS of Antimony is a metallic ſubſtance of a pretty bright white colour. It has the ſplendour, opacity, and gravity of a metal: but it is quite unmalleable, and crumbles to duſt, inſtead of yielding or ſtretching, under the hammer; on which account it is claſſed with the Semi-metals.

It begins to flow as ſoon as it is moderately red; but, like the other Semi-metals, it cannot ſtand a violent degree of fire; being thereby diſſipated into ſmoke and white vapours, which adhere to ſuch cold bodies as they meet with, and ſo are collected into a kind of *farina* called *Flowers of Antimony.*

If Regulus of Antimony, inſtead of being expoſed to a ſtrong fire, be only heated ſo moderately that it ſhall not even melt, it will calcine, loſe its phlogiſton, and take the form of a greyiſh powder deſtitute of all ſplendour: this powder is called *Calx of Antimony.*

This calx is not volatile like the Regulus, but will endure a very violent fire; and being expoſed thereto will flow, and turn to a glaſs of the yellowiſh colour of a hyacinth.

It is to be obſerved that the more the Regulus is deprived of its phlogiſton by continued calcination, the more refractory is the calx obtained from it. The glaſs thereof has alſo ſo much the leſs colour, and comes the nearer to common glaſs.

The Calx and the Glaſs of Antimony will recover their metalline form, like every other Calx and Glaſs of a metal, if reduced by reſtoring to them their loſt phlogiſton. Yet if the calcination be carried too far, their reduction will become much more difficult, and a much ſmaller quantity of Regulus will be reſuſcitated.

Regulus of Antimony is capable of diſſolving the metals; but its affinities with them are various, and differ according to the following order. It affects Iron the moſt powerfully, next Copper, then Tin, Lead, and Silver. It promotes the fuſion of metals, but makes them all brittle and unmalleable.

It will not amalgamate with Mercury; and though by certain proceſſes, particularly the addition of water and continued trituration, a ſort of union between theſe two ſubſtances may be produced, yet it is but apparent and momentary; for being left to themſelves and undiſturbed they quickly diſunite and ſeparate *.

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* M. Malouin, however, hath found a way to unite theſe two metallic ſubſtances: but then he does it by the interpoſition of ſulphur; that is, he combines crude Antimony with Mercury. This combination is brought about in the ſame way that Æthiops mineral is made; viz. either by fuſion, or by trituration only without fire. It reſembles the common Æthiops, and M. Malouin calls it *Æthiops of Antimony.* He obſerved that Mercury unites with Antimony much more intimately, by melting than by rubbing them together.

The vitriolic acid, aſſiſted by heat, and even by diſtillation, diſſolves Regulus of Antimony. The nitrous acid likewiſe attacks it; but the ſolution can by no art be made clear and limpid: ſo that the Regulus is only calcined, in a manner, by this acid.

The marine acid diſſolves it well enough; but then it muſt be exceedingly concentrated, and applied in a peculiar manner, and eſpecially by diſtillation. One of the beſt methods of procuring a perfect union between the acid of ſea-ſalt and Regulus of Antimony, is to pulverize the latter, mix it with corroſive ſublimate, and diſtill the whole. There riſes in the operation a white matter, thick and ſcarce fluid, which is no other than the Regulus of Antimony united and combined with the acid of ſea-ſalt. This compound is extremely corroſive, and is called *Butter of Antimony.*

It is plain that the corroſive ſublimate is here decompounded; that the Mercury is revivified, and that the acid which was combined therewith hath quitted it to join the Regulus of Antimony, with which its affinity is greater. This Butter of Antimony by repeated diſtillations acquires a conſiderable degree of fluidity and limpidneſs.

If the acid of nitre be mixed with Butter of Antimony, and the whole diſtilled, there riſes an acid liquor, or a ſort of *aqua regis*, which ſtill retains ſome of the diſſolved Regulus, and is called *Bezoardic Spirit of Nitre.* After the diſtillation there remains a white matter, from which freſh ſpirit of nitre is again abſtracted, and which being then waſhed with water is called *Bezoar mineral.* This Bezoar mineral is neither ſo volatile, nor ſo cauſtic, as Butter of Antimony; becauſe the nitrous acid hath not the property of volatilizing metallic ſubſtances, as the marine acid does, and becauſe it remains much more intimately combined with the reguline part.

If Butter of Antimony be mixed with water, the liquor immediately becomes turbid and milky, and a precipitate falls, which is nothing but the metallic matter partly ſeparated from its acid, which is too much weakened by the addition of water to keep it diſſolved. Yet this precipitate ſtill retains a good deal of acid; for which reaſon it continues to be a violent emetic, and in ſome degree corroſive. It hath therefore been very improperly called *Mercurius Vitæ.*

The proper ſolvent of Regulus of Antimony is *aqua regis*; by means whereof a clear and limpid ſolution of this Semi-metal may be obtained.

Regulus of Antimony mixed with nitre, and projected into a red-hot crucible, ſets the nitre in a flame, and makes it detonate. As it produces this effect by means of its phlogiſton, it muſt needs at the ſame time be calcined, and loſe its metallic properties, which accordingly happens: and when the nitre is in a triple proportion to the Regulus, the latter is ſo perfectly calcined as to leave only a white powder, which is fuſed with great difficulty, and then turns to a faintly coloured glaſs, not very different from common glaſs, and which is not reducible to a Regulus by the addition of inflammable matter; at leaſt it yields but a very ſmall quantity thereof. If leſs nitre be uſed, the calx is not ſo white; the glaſs it produces is more like a metalline glaſs, and is more eaſily reduced. The calx of the Regulus thus prepared by nitre is called, on account of the medicinal virtue aſcribed to it, *Diaphoretic antimony*, or *Diaphoretic mineral.*

Nitre always becomes an alkali by deflagration, and in the preſent caſe retains part of the calx, which it even renders ſoluble in water. This calx may be ſeparated from the alkali, if an acid be employed to precipitate it; and then it is called *Materia perlata.* This pearly matter is a calx of Antimony, ſo completely deprived of its phlogiſton as to be altogether incapable of reduction to a Regulus.

Regulus of Antimony readily joins and unites with ſulphur, forming therewith a compound which has a very faint metallic ſplendour. This compound appears like a maſs of long needles adhering together laterally; and under this form it is uſually found in the ore, or at leaſt when only ſeparated by fuſion from the ſtones and earthy matters with which the ore is mixed. It is called *Crude Antimony*.

Antimony flows with a moderate heat, and becomes even more fluid than other metallic ſubſtances. The action of fire diſſipates or conſumes the ſulphur it contains, and its phlogiſton alſo, ſo as to convert it into a calx and a glaſs, as it does the Regulus.

Aqua regis, which we obſerved to be the proper ſolvent of the Regulus, being poured on Antimony attacks and diſſolves the reguline part, but touches not the ſulphur; in conſequence whereof it decompoſes the Antimony, and ſeparates its ſulphur from its Regulus.

There are ſeveral other ways of effecting this decompoſition, and obtaining the reguline part of Antimony by itſelf: they conſiſt either in deſtroying the ſulphureous part of the Antimony by combuſtion, or in melting the Antimony with ſome ſubſtance which has a greater affinity than its reguline part with ſulphur. Moſt metals are very fit for this latter purpoſe: for though the Regulus has a conſiderable affinity with ſulphur, yet all the metals, except Gold and Mercury, have a greater.

If therefore Iron, Copper, Lead, Silver, or Tin, be melted with Antimony, the metal employed will unite with the ſulphur, and ſeparate it from the Regulus.

It muſt be obſerved that, as theſe metals have ſome affinity with the Regulus of Antimony, the Regulus will be joined in the operation by ſome of the metal employed as a *Precipitant*, (ſo thoſe ſubſtances are called which ſerve as the means of ſeparating two bodies from each other;) and therefore the Regulus procured in this manner will not be abſolutely pure: on this account care is taken to diſtinguiſh each by adding the name of the metal employed in its precipitation; and thence come theſe titles, *Martial Regulus of Antimony*, or only *Martial Regulus*, *Regulus Veneris*; and ſo of the reſt.

Antimony is employed with advantage to ſeparate Gold from all the other metals with which it may be alloyed. It has been ſhewn that all the metals have a greater affinity, than the reguline part of Antimony, with ſulphur, Gold only excepted; which is incapable of contracting any union therewith: and therefore, if a maſs compounded of Gold and ſeveral other metals be melted with Antimony, every thing in that maſs which is not Gold will unite with the ſulphur of the Antimony. This union occaſions two ſeparations, to wit, that of the ſulphur of the Antimony from its reguline part, and that of the Gold from the metals with which it was adulterated; and from the whole two new compounds ariſe; namely, a combination of the metals with the ſulphur, which being lighteſt riſes to the ſurface in fuſion; and a metalline maſs formed of the Gold and the reguline part of the Antimony united together, which being much the heavieſt ſinks to the bottom. There is no difficulty in parting the Gold from the Regulus of Antimony with which it is alloyed: for the metalline maſs need only be expoſed to a degree of fire capable of diſſipating into vapours all the Semi-metal it contains; which being very volatile, the operation is much eaſier, and more expeditiouſly finiſhed, than if the metals with which the Gold was debaſed were to be vitrified on the cupel; without taking into the account that if Silver were one of them, recourſe muſt needs be had to the proceſs of quartation after that of the cupel.

If equal parts of nitre and Antimony be mixed together, and the mixture expoſed to the action of fire, a violent detonation enſues; the nitre deflagrating conſumes the ſulphur of the Antimony, and even a part of its phlogiſton. After the detonation there remains a greyiſh matter which contains fixed nitre, vitriolated tartar, and the reguline part of the Antimony in ſome meaſure deprived of its phlogiſton, and half vitrified by the action of the fire, which is conſiderably increaſed by the deflagration. This matter is called *Liver of Antimony.*

If inſtead of equal parts of nitre and Antimony, two parts of the former be uſed to one of the latter, then the reguline part loſes much more of its phlogiſton, and remains in the form of a yellowiſh powder.

Again, if three parts of nitre be taken to one of Antimony, the Regulus is thereby entirely robbed of its phlogiſton, and converted to a white calx which bears the name of *Diaphoretic Antimony*, or *Diaphoretic Mineral.* The pearly matter may be precipitated by pouring an acid on the ſaline ſubſtances which here remain after the detonation, in the ſame manner as we ſhewed above was to be done with regard to the Regulus.

In the laſt two operations, where the nitre is in a double or triple proportion to the Antimony, the reguline part is found after the detonation to be converted into a calx, and not into a half vitrified matter, which we have ſeen is the effect when equal parts only of nitre and Antimony are uſed. The reaſon of this difference is, that in theſe two caſes the reguline part, being wholly, or almoſt wholly, deprived of its phlogiſton, becomes, as was obſerved, more difficult to fuſe, and conſequently cannot begin to vitrify in the ſame degree of heat as that which hath not loſt ſo much of its phlogiſton. If inſtead of performing the operation with equal parts of nitre and Antimony alone, a portion of ſome ſubſtance which abounds with phlogiſton be added, in that caſe the ſulphur only of the Antimony will be conſumed, and the Regulus will remain united with its phlogiſton and ſeparated from its ſulphur.

The Regulus prepared in this manner is abſolutely pure, becauſe no metalline ſubſtance being employed, none can mix with and adulterate it. It is called *Regulus of Antimony per ſe*, or only *Regulus of Antimony*.

It is true indeed that in this operation much of the reguline part unavoidably loſes its phlogiſton and is calcined, and conſequently a much ſmaller quantity of Regulus is obtained than when metalline precipitants are employed: but this loſs is eaſily repaired, if it be thought proper, by reſtoring to the calcined part its loſt phlogiſton.

Antimony melted with two parts of fixed alkali yields no Regulus, but is entirely diſſolved by the ſalt, and forms with it a maſs of a reddiſh yellow colour.

The reaſon why no precipitate is produced on this occaſion is, that the alkali uniting with the ſulphur of the Antimony forms therewith the combination called Liver of Sulphur, which by its nature is qualified to keep the reguline part diſſolved. This maſs formed by the union of the Antimony with the alkali is ſoluble in water. If any acid whatever be dropt into this ſolution, there falls a precipitate of a reddiſh yellow colour; becauſe the acid unites with the alkali, and forces it to quit the matters with which it was combined. This precipitate is called *Golden Sulphur of Antimony*.

As in the operation for preparing Regulus of Antimony *per ſe*, ſome of the nitre is, by the inflammable matters added thereto, turned to an alkali; this alkali ſeizes on part of the Antimony, and therewith forms a compound like that juſt deſcribed. Hence it comes that if the ſcoria formed in this proceſs be diſſolved in water, and an acid dropped into the ſolution, a true golden ſulphur of Antimony is thereby ſeparated.

This union of Antimony with an alkali may alſo be brought about by the humid way; that is, by making uſe of an alkali reſolved into a liquor, and boiling the mineral in it. The alkaline liquor, in proportion as it acts upon the Antimony, gradually becomes reddiſh and turbid. If left to ſettle and cool when well ſaturated therewith, it gradually depoſites the Antimony it had taken up, which precipitates in the form of a red powder: and this precipitate is the celebrated remedy known by the name of *Kermes mineral.* It is plain that the kermes is nearly the ſame thing with the golden ſulphur: yet it differs from it in ſome reſpects; and eſpecially in this, that being taken inwardly it operates much more gently than the golden ſulphur, which is a violent emetic. Nitre fixed by charcoal, and reſolved into a liquor, is the only alkali employed in preparing the kermes.

It was ſhewn above that Regulus of Antimony mixed and diſtilled with corroſive ſublimate decompounds it, diſengages the Mercury, and joining itſelf to the marine acid forms therewith a new combination, called Butter of Antimony. If the ſame operation be performed with crude Antimony inſtead of its Regulus, the ſame effects are produced: but then the Antimony itſelf is alſo decompoſed; that is, the reguline part is ſeparated from the ſulphur, which being ſet free unites with the Mercury, now alſo at liberty, and theſe two together form a true cinabar called *Cinabar of Antimony.*

§. II. *Of* BISMUTH.

BISMUTH, known alſo by the name of Tin-glaſs, is a ſemi-metal, having almoſt the ſame appearance as Regulus of Antimony; yet it has a more duſky caſt, inclining ſomewhat to red, and even preſents ſome changeable ſtreaks, eſpecially after lying long in the air.

When expoſed to the fire it melts long before it is red, and conſequently with leſs heat than Regulus of Antimony, which does not flow, as was ſhewn above, till it begin to be red-hot. It becomes volatile, like all the other ſemi-metals, when acted on by a violent fire: being kept in fuſion by a proper degree of heat it loſes its phlogiſton with its metallic form, and turns to a powder or a calx; and that again is converted into glaſs by the continued action of fire. The calx and glaſs of Biſmuth may be reduced, like any other metallic calx, by reſtoring their phlogiſton.

Biſmuth mixes with all the metals in fuſion, and even facilitates the fuſion of ſuch as do not otherwiſe flow readily. It whitens them by its union, and deſtroys their malleability.

It amalgamates with Mercury, if they be rubbed together with the addition of water: yet after ſome time theſe two metalline ſubſtances deſert each other, and the Biſmuth appears again in the form of a powder. Hence it is plain that the union it contracts with Mercury is not perfect; and yet it it has the ſingular property of attenuating Lead, and altering it in ſuch a manner that it afterwards amalgamates with Mercury much more perfectly, ſo as even to paſs with it through ſhamoy leather without any ſeparation. The Biſmuth employed in making this amalgama afterwards ſeparates from it ſpontaneouſly,

neouſly, as uſual; but the Lead ſtill continues united with the Mercury, and always retains the property thus acquired.

The vitriolic acid does not diſſolve Biſmuth: its proper ſolvent is the nitrous acid, which diſſolves it with violence, and abundance of fumes.

Biſmuth diſſolved in the nitrous acid is precipitated not only by alkalis, but even by the bare addition of water. This precipitate is extremely white, and known by the name of *Magiſtery of Biſmuth.*

The acid of ſea-ſalt and *aqua regis* likewiſe act upon Biſmuth, but with leſs violence.

This ſemi-metal does not ſenſibly deflagrate with nitre; yet it is quickly deprived of its phlogiſton, and turned into a vitrifiable calx, when expoſed with it to the action of fire.

It readily unites with ſulphur in fuſion, and forms therewith a compound which appears to conſiſt of needles adhering laterally to each other.

It may be ſeparated from the ſulphur with which it is combined, by only expoſing it to the fire, without any additament; for the ſulphur is either conſumed or ſublimed, and leaves the Biſmuth behind.

§. III. *Of* ZINC.

ZINC to appearance differs but little from Biſmuth, and has even been confounded with it by ſeveral authors. Nevertheleſs, beſides that it has ſomething of a blueiſh caſt, and is harder than Biſmuth, it differs from it eſſentially in its properties, as will preſently be ſhewn. Theſe two metallic ſubſtances ſcarce reſemble each other in any thing, but the qualities common to all ſemi-metals.

Zinc melts the moment it grows red in the fire, and then alſo begins to turn to a calx, which, like any other metallic calx, may be reduced by means of the phlogiſton: but if the fire be conſiderably increaſed, it ſublimes, flames, and burns like an oily matter; which is a proof of the great quantity of phlogiſton in its compoſition. At the ſame time abundance of flowers riſe from it in the form of white flakes, flying about in the air like very light bodies; and into this form may the whole ſubſtance of the Zinc be converted. Several names have been given to theſe flowers, ſuch as Pompholix, Philoſophic Wool. They are ſuppoſed to be no other than the Zinc itſelf deprived of its phlogiſton; yet no body has hitherto been able to reſuſcitate them in the form of Zinc, by reſtoring their phlogiſton according to the methods uſed in the reduction of metals. Though they riſe in the air with very great eaſe while the Zinc is calcining, yet when once formed they are very fixed; for they withſtand the utmoſt violence of fire, and are capable of being vitrified, eſpecially if joined with a fixed alkali. They are ſoluble in acids.

Zinc unites with all metalline ſubſtances, except Biſmuth. It has this ſingular property, that being mixed with Copper, even in a conſiderable quantity, ſuch as a fourth part, it does not greatly leſſen the ductility thereof, and at the ſame time communicates to it a very beautiful colour not unlike that of Gold: on which account the compoſition is frequently made, and produces what is called *Braſs*. This metal melts much more eaſily than Copper alone, becauſe of the Zinc with which it is alloyed. If it be expoſed to a great degree of heat, the Zinc which it contains takes fire, and ſublimes in white flowers, juſt as when it is pure.

It is to be obſerved that Braſs is ductile only while it is cold, and not then unleſs the Zinc uſed in making it was very pure; otherwiſe the compoſition will prove but a *Tombac* or *Prince's Metal*, having very little malleability.

Zinc is very volatile, and carries off with it any metallic ſubſtance with which it is fuſed, making a kind of ſublimate thereof. In the furnaces where they ſmelt ores containing Zinc, the matter thus ſublimed is called *cadmia fornacum*, to diſtinguiſh it from the native *cadmia* called alſo *calamine*, or *lapis calaminaris*; which, properly ſpeaking, is an ore of Zinc, containing a great deal of that ſemi-metal, together with ſome iron, and a ſtony ſubſtance. The name of *cadmia fornacum* is not appropriated ſolely to the metallic ſublimates procured by means of Zinc, but is given in general to all the metallic ſublimates found in ſmelting-houſes.

If a violent and ſudden heat be applied to Zinc, it ſublimes in its metalline form; there not being time for it to burn and be reſolved into flowers.

This ſemi-metal is ſoluble in all the acids, but eſpecially in ſpirit of nitre, which attacks and diſſolves it with very great violence.

Zinc has a greater affinity than iron or copper with the vitriolic acid; and therefore it decompounds the green and blue vitriols, precipitating thoſe two metals by uniting with the vitriolic acid, with which it forms a metallic ſalt or vitriol called *White Vitriol*, or *Vitriol of Zinc*.

Nitre mixed with Zinc and projected into a red-hot crucible detonates with violence, and during the detonation there riſes a great quantity of white flowers, like thoſe which appear when it is calcined by itſelf.

Sulphur has no power over Zinc. Even liver of ſulphur, which diſſolves all other metallic ſubſtances, contracts no union with this ſemi-metal.

Meſſ. Hellot and Malouin have beſtowed a great deal of pains on this ſemi-metal. An account of their experiments is to be found in the Memoirs of the Academy of Sciences.

§. IV. *Of*

§. IV. *Of* REGULUS OF ARSENIC.

REGULUS of Arſenic is the moſt volatile of all the ſemi-metals. A very moderate heat makes it wholly evaporate, and fly off in fumes; on which account it cannot be brought to fuſion, nor can any conſiderable maſſes thereof be obtained. It has a metallic colour, ſomewhat reſembling Lead; but it ſoon loſes its ſplendour when expoſed to the air.

It unites readily enough with metallic ſubſtances, having the ſame affinities with them as Regulus of Antimony hath. It makes them brittle, and unmalleable. It hath alſo the property of rendering them volatile, and greatly facilitates their ſcorification.

It very eaſily parts with its phlogiſton and its metallic form. When expoſed to the fire it riſes in a kind of ſhining cryſtalline calx, which on that account looks more like a ſaline matter than a metallic calx. To this calx or theſe flowers are given the names of *White Arſenic*, *Cryſtalline Arſenic*, and moſt commonly plain *Arſenic*.

The properties of this ſubſtance are very ſingular, and extremely different from thoſe of any other metallic calx. Hitherto it hath been but little examined; and this led me to make ſome attempts towards diſcovering its nature, which may be ſeen in the Memoirs of the Academy of Sciences.

Arſenic differs from every other metalline calx, firſt, in being volatile; whereas the calxes of all other metallic ſubſtances, not excepting thoſe of the moſt volatile ſemi-metals, ſuch as Regulus of Antimony and Zinc, are exceedingly fixed; and ſecondly, in having a ſaline character, which is not found in any other metalline calx.

The ſaline character of Arſenic appears, firſt, from its being ſoluble in water; ſecondly, from its corroſive quality, which makes it one of the moſt violent poiſons: a quality from which the other metallic ſubſtances are free, when they are not combined with ſome ſaline matter. Regulus of Antimony muſt however be excepted: but then the beſt Chymiſts agree that this ſemi-metal is either nearly of the ſame nature with Arſenic, or contains a portion thereof in its compoſition: beſides, its noxious qualities never diſcover themſelves ſo plainly as when it is combined with ſome acid. Laſtly, Arſenic acts juſt like the vitriolic acid upon nitre; that is, it decompounds that neutral ſalt, by expelling it from its alkaline baſis, of which it takes poſſeſſion, and therewith forms a new ſaline compound.

This combination is a ſpecies of ſalt that is perfectly neutral. When the operation is performed in a cloſe veſſel, the ſalt ſhoots into cryſtals in the form of right-angled quadrangular priſms, terminated at each extremity by pyramids that are alſo quadrangular and right-angled; ſome of which, however, inſtead of ending in a point, are obtuſe as if truncated. The conſequence is different when the operation is performed in an open veſſel; for then nothing is obtained but an alkaline ſalt impregnated with Arſenic, which cannot be cryſtallized.

The cauſe of this different effect is that, when the Arſenic is once engaged in the alkaline baſis of the nitre, it can never be ſeparated from it by the utmoſt force of fire, ſo long as it is kept in a cloſe veſſel; whereas, if you expoſe it to the fire without that precaution, it readily ſeparates from it. This property of Arſenic was never before obſerved by any Chymiſt, and therefore this our new ſpecies of Neutral arſenical ſalt was abſolutely unknown till lately.

This new ſalt poſſeſſes many ſingular properties, the chief of which are theſe: Firſt, it cannot be decompounded by the intervention of any acid, even the ſtrongeſt acid of vitriol; and this, joined to its property of expelling the nitrous acid from its baſis, ſhews that it has a very great affinity with fixed alkalis.

Secondly, this very ſalt, on which pure acids have no effect, is decompounded with the greateſt eaſe by acids united with metallic ſubſtances. The reaſon of this phenomenon is curious, and furniſhes us with an inſtance of what we advanced concerning double affinities.

If to a ſolution of any metallic ſubſtance whatever, made by any acid whatever, (except that of Mercury by the marine acid, and that of Gold by *aqua regis*,) a certain quantity of our new ſalt diſſolved in water be added, the metallic ſubſtance is inſtantaneouſly ſeparated from the acid in which it was diſſolved, and falls to the bottom of the liquor.

All metallic Precipitates obtained in this manner are found to be a combination of the metal with Arſenic; whence it neceſſarily follows that the new Neutral Salt is by this means decompounded, its arſenical part uniting with the metallic ſubſtance, and its alkaline baſis with the acid in which that ſubſtance was diſſolved.

The affinities of theſe ſeveral bodies muſt be conſidered as operating on this occaſion in the following manner: The acids which tend to decompound the Neutral Salt of Arſenic, by virtue of their affinity with its alkaline baſis, are not able to accompliſh it, becauſe this affinity is powerfully counteracted by that which the Arſenic has with the ſame alkaline baſis, and which is equal or even ſuperiour to theirs. But if theſe acids happen to be united with a ſubſtance which naturally has a very great affinity with the arſenical part of the Neutral Salt, then, the two parts of which this Salt conſiſts being drawn different ways by two ſeveral affinities tending to ſeparate them from each other, the Salt will undergo a decompoſition, which could not have been effected without the help of this ſecond affinity. Now as metallic ſubſtances have a great affinity with Arſenic, it is not ſurpriſing that the Neutral Salt of arſenic, which cannot be decompounded by a pure acid, ſhould nevertheleſs yield to an acid combined with a metal. The decompoſition of this Salt, therefore, and the precipitation which of courſe it produces in metallic ſolutions, are brought about by the means of a double affinity; namely, that of the acid with the alkaline baſis of the Neutral ſalt, and that of the metal with the arſenical part of that ſalt.

Arſenic has not the ſame effect on ſea-ſalt as on nitre, and cannot expel its acid: a very ſingular phenomenon, for which it is hard to aſſign a reaſon; for the nitrous acid is known to have a greater affinity than the marine acid with alkalis, and even with the baſis of ſea-ſalt itſelf.

Yet Arſenic may be combined with the baſis of ſea-ſalt, and a Neutral ſalt thereby obtained, like that which reſults from the decompoſition of nitre by Arſenic: but for that purpoſe a quadrangular nitre muſt be firſt prepared, and Arſenic applied thereto as to common nitre.

The Salt produced by uniting Arſenic with the baſis of ſea-ſalt very much reſembles the Neutral ſalt of Arſenic above treated of, as well in the figure of its cryſtals as in its ſeveral properties.

Arſenic preſents another ſingular phenomenon, both with the alkali of nitre and with that of ſea-ſalt; which is, that if it be combined with theſe ſalts in a fluid ſtate, it forms with them a ſaline compound, quite different from the Neutral ſalts of arſenic which reſult from the decompoſition of nitrous ſalts.

This ſaline compound, which I call *Liver of Arſenic*, takes up a much greater quantity of Arſenic than is neceſſary for the perfect ſaturation of the alkali, It has the appearance of a glue, which is ſo much the thicker the more Arſenic it contains. Its ſmell is diſagreeable; it attracts the moiſture of the air, and does not cryſtallize; it is eaſily decompounded by any acid whatever, which precipitates the Arſenic and unites with the alkali. Laſtly, the effects it produces on metallic ſolutions are different from thoſe of our neutral arſenical ſalts. But the bounds which I have ſet my ſelf in this treatiſe will not allow me to be more particular. Such as have the curioſity to enquire further into the ſubject may conſult my Diſſertations on Arſenic, publiſhed among the Memoirs of the Academy of Sciences.

Arſenic is eaſily reduced to a Regulus. It need only be mixed with any matter containing the phlogiſton, and by the help of a moderate heat a true Regulus will ſublime. This Regulus, as was ſaid, is very volatile, and calcines with the greateſt eaſe; which is the reaſon why it cannot be obtained but in ſmall quantities, and alſo why, in order to obtain maſſes of it, ſome have thought of adding thereto ſome metal with which it has a great affinity, ſuch as Copper or Iron; becauſe by joining with the metal it is partly fixed and reſtrained from flying off. But it is plain the Regulus obtained by this means is not pure, as it muſt partake conſiderably of the metal employed.

Arſenic readily unites with ſulphur, and riſes with it in a yellow compound called *Orpiment*.

Sulphur cannot be ſeparated from Arſenic but by the intervention of two bodies only; to wit, a fixed alkali and Mercury.

The property which Mercury poſſeſſes of ſeparating ſulphur from Arſenic is founded on this, that theſe two metallic ſubſtances are incapable of contracting any union; whereas though moſt of the other metals and ſemi-metals have a greater affinity with ſulphur than Mercury hath, as was ſhewn in treating of the decompoſition of Cinabar, nevertheleſs they are all unable to decompound Orpiment; becauſe ſome of them have as great an affinity with Arſenic as with ſulphur; others have no affinity with either; and laſtly, ſulphur hath as great an affinity with Arſenic as with any of them.

It muſt be obſerved that, if fixed alkalis be employed to purify Arſenic in this manner, no more muſt be uſed than is neceſſary to abſorb the ſulphur or the phlogiſton, of which alſo it is their nature to deprive Arſenic; for otherwiſe, as it has been ſhewn that Arſenic readily unites with alkalis, they would abſorb a conſiderable quantity thereof.

CHAP. X.

Of OIL *in general.*

OIL is an unctuous body, which burns and conſumes with flame and ſmoke, and is not ſoluble in water. It conſiſts of the phlogiſton united with water by means of an acid. There is moreover in its compoſition a certain proportion of earth, more or leſs according to each ſeveral ſort of Oil.

The inflammability of Oil evidently proves that it contains the phlogiſton. That an acid is one of its conſtituent principles many experiments demonſtrate, of which theſe are the chief: If certain Oils be long triturated with an alkaline ſalt, and the alkali afterwards diſſolved in water, cryſtals of a true neutral ſalt will be produced: ſome metals, and particularly Copper, are corroded and ruſted by Oils, juſt as they are by acids: again, acid cryſtals are found in ſome Oils that have been long kept. This acid in Oil ſerves undoubtedly to unite its phlogiſton with its water; becauſe theſe two ſubſtances having no affinity with each other cannot be united without the intervention of ſuch a medium as an acid, which has an affinity with both. As to the exiſtence of water in Oils, it appears plainly when they are decompoſed by repeated diſtillations, eſpecially after mixing them with abſorbent earths. Laſtly, when an Oil is deſtroyed by burning, a certain quantity of earth is conſtantly left behind.

We are very ſure that the abovementioned principles enter into the compoſition of Oils; for they may be obtained from every one of them: but it is not abſolutely certain that they conſiſt of theſe only, and that they do not contain ſome other principle which may eſcape our notice in decompoſing them, for hitherto it doth not appear, by any experiment we can depend on, that Oil was ever produced by combining together the principles here ſpecified: yet ſuch redintegrations are the only means we have of ſatisfying ourſelves that we know all the principles which conſtitute a body.

Oils expoſed to the fire in cloſe veſſels paſs over almoſt wholly from the containing veſſel into any other applied to receive them. There remains, however, a ſmall quantity of black matter, which is extremely fixed, and continues unalterable as long as it has no communication with the external air, be the force of the fire ever ſo violent. This matter is no other than part of the phlogiſton of the Oil united with its moſt fixed and groſſeſt earth; and this is what we called *Charcoal*, or plainly a *Coal*.

§. I. *Of* CHARCOAL.

WHEN Oil happens to be united to much earth, as it is in vegetable and animal bodies, it leaves a conderable quantity of *Coal* or Charred matter.

This Coal, expoſed to the fire in the open air, burns and waſtes, but without blazing like other combuſtible matters: there appears only a ſmall blueiſh flame, but not the leaſt ſmoke. Moſt commonly it only glows and ſparkles, and ſo gradually falls into aſhes, which are nothing but the earth of the body combined with an alkaline ſalt in burning. This alkaline ſalt may be ſeparated from the earth, by lixiviating the aſhes with water, which diſſolves all the ſalt, and leaves the earth quite pure.

Charcoal is unalterable and indeſtructible by any other body but fire; whence it follows, that when it is not actually kindled and ignited, the moſt powerful agents, ſuch as the acids, though ever ſo ſtrong and concentrated, have not the leaſt effect on it.

The caſe is otherwiſe when it is lighted, that is, when its phlogiſton begins to ſeparate from its earth; for then the pure acid of vitriol being joined therewith contracts an inſtantaneous union with its phlogiſton, and evaporates in a volatile ſulphureous ſpirit. If the vitriolic acid, inſtead of being applied quite pure, be firſt clogged with ſome baſis, eſpecially an alkaline one, it quits that baſis, enters into a more intimate union with the phlogiſton of the burning Coal, and ſo forms an actual ſulphur, with which the alkali now unites and forms a hepar.

The pure acid of ſea-ſalt hath not been obſerved to act in the leaſt upon Charcoal, eſpecially when it is not on fire. But when this acid is incorporated with an alkaline or metallic baſis, and combined according to a peculiar proceſs with burning Charcoal, it in like manner quits its baſis, unites with the phlogiſton, and therewith forms a Phoſphorus, of which we have already taken notice.

Nor has the pure nitrous acid any effect on a charred Coal, even when ignited: and ſo far is it from being able to kindle a cold one, that when poured on a live one, it extinguiſhes it like water. But when this acid is united with a baſis, it quits it rapidly as ſoon as it touches a burning coal, and ruſhes violently into an union with the phlogiſton thereof. From this union there probably ariſes, as we ſaid before, a kind of ſulphur or phoſphorus, which is ſo inflammable as to be deſtroyed by the fire the very moment it is generated.

The acids of nitre and vitriol act upon Oils; but very differently, according to the quantity of phlegm they contain. If they be weakened with much water, they have no effect at all upon Oils; if they contain little water, or be dephlegmated to a certain degree, they diſſolve them with heat, and with them form compounds of a thick conſiſtence. Acids thus combined in a conſiderable proportion with Oils render them ſoluble in water.

§. II. *Of* SOAP.

ALKALIS alſo have the ſame property. When an Oil is combined with an acid or an alkali in ſuch a manner that the compound reſulting from their union is ſoluble in water; ſuch a compound may in general be called a *Soap*. Soap itſelf hath the property of rendering fat bodies in ſome meaſure ſoluble in water; on which account it is very uſeful for ſcouring or cleanſing any thing greaſy.

Oily and ſaline ſubſtances, combined together, obſerve the ſame general rules as all other combinations; that is, they mutually communicate the properties belonging to each: thus Oils, which naturally are not ſoluble in water, acquire by their union with ſaline matters the property of diſſolving therein; and ſalts loſe by their conjunction with Oils part of their natural tendency to incorporate with water; ſo that while they ſerve to conſtitute Soap they do not, as before, attract the moiſture of the air, *&c.* and in like manner, as they are not in-

inflammable, they conſiderably leſſen the inflammability of the Oils combined with them.

Acid Soaps are decompounded by alkalis, as alkaline Soaps are by acids, according to the general rules of affinities.

The acids of nitre and vitriol, when highly concentrated, diſſolve Oils with ſuch violence as to heat them, make them black, burn them, and even ſet them on fire. How ſea-ſalt affects Oils is not yet ſufficiently aſcertained.

All Oils have the property of diſſolving ſulphur; which is not at all ſurpriſing, ſeeing each of its component principles hath an affinity with Oil.

It is alſo a property common to all Oils to become more fluid, ſubtile, light, and limpid the oftener they are diſtilled. On the contrary, by being incorporated with ſaline ſubſtances they acquire a greater conſiſtence, and ſometimes form compounds that are almoſt ſolid.

CHAP. XI.

Of the ſeveral ſorts of OILS.

OILS are diſtinguiſhed by the ſubſtances from which they are drawn: and as Oils are extracted from minerals, from vegetables, and from animals, there are of courſe Mineral, Vegetable, and Animal Oils.

§. I. *Of* MINERAL OILS.

IN the bowels of the earth we find but one ſort of Oil, called *Petroleum*: its ſmell is ſtrong and not diſagreeable, and its colour ſometimes more ſometimes

times leſs yellow. There are certain mineral ſubſtances which yield by diſtillation a great deal of Oil very like Petroleum. This ſort of ſubſtance is called a *Bitumen*, and is, indeed, nothing but an Oil rendered conſiſtent and ſolid by being combined with an acid; as appears from hence, that by uniting Petroleum with the acid of vitriol we can produce an artificial Bitumen very like the native.

§. II. *Of* VEGETABLE OILS.

VEGETABLE ſubſtances yield a very great quantity and variety of Oils: for there is not a plant, or part of a plant, that does not contain one or more ſorts thereof, generally peculiar to itſelf, and different from all others.

By expreſſion only, that is, by bruizing and ſqueezing vegetable ſubſtances, particularly certain fruits and ſeeds, a ſort of Oil is obtained which has ſcarce any ſmell or taſte. Oils of this ſort are very mild and unctuous; and, becauſe in this reſpect they reſemble animal fat more than the reſt do, they are called *Fat Oils*.

Theſe Oils, being expoſed to the air for ſome time, ſooner or later grow thick, acquire an acrid taſte, and a ſtrong diſagreeable ſmell. Some of them congeal with the ſmalleſt degree of cold. This ſort of Oil is well adapted to diſſolve thoſe preparations of Lead called Litharge and Minium, with which they form a thick tenacious ſubſtance, that is uſed for the baſis of almoſt all plaiſters. They alſo diſſolve Lead in its metalline form; but not ſo eaſily as the ſorts of calx abovementioned; probably becauſe its body is not ſo much opened, nor its parts ſo divided.

By expreſſion alone we alſo procure from certain vegetable ſubſtances another ſort of Oil, which is thin, limpid, volatile, of a pungent taſte, and retains the ſmell of the vegetable that yielded it; on which account it is called an *Eſſential Oil*. Of this there are ſeveral ſorts, differing from one another, like the Fat Oils, according to the ſubjects from which they are obtained.

We muſt obſerve that it is very difficult, or rather in moſt caſes impoſſible, to force from the greateſt part of vegetables, by expreſſion only, all the eſſential Oil they contain. For this purpoſe therefore recourſe muſt be had to fire: a gentle heat, not exceeding that of boiling water, will extract all the eſſential Oils of a vegetable; and this is the moſt uſual and moſt convenient way of procuring them.

The fat Oils cannot be obtained by the ſame method: theſe being much leſs volatile than the eſſential Oils require a much greater degree of heat to raiſe them; which nevertheleſs they cannot bear without being much ſpoiled and entirely changed in their nature, as ſhall preſently be ſhewn. All Oils, therefore, which riſe with the heat of boiling water, and ſuch alone, ſhould be called Eſſential Oils.

Eſſential Oils, in a longer or ſhorter time, according to the nature of each, loſe the fragrant ſmell they had when newly diſtilled, and acquire another which is ſtrong, rancid, and much leſs agreeable: they alſo loſe their tenuity, becoming thick and viſcid; and in this ſtate they greatly reſemble thoſe ſubſtances abounding in Oil which flow from certain trees, and which are called *Balſams* or *Reſins*, according as they are leſs or more conſiſtent.

Balſams and Reſins are not ſoluble in water. But there are other Oily compounds which likewiſe run from trees; and, though not unlike Reſins, are however ſoluble in water. Theſe are called *Gums*; and their property of diſſolving in water ariſes from their containing more water and more ſalt than Reſins have; or at leaſt their ſaline parts are leſs clogged and more diſengaged.

Balſams and Reſins diſtilled with the heat of boiling water yield great quantities of a limpid, ſubtle, odoriferous, and, in one word, eſſential Oil. In the ſtill there remains a ſubſtance thicker and more conſiſtent than the Balſam or Reſin was before diſtillation. The ſame thing happens to eſſential Oils which by length of time have acquired a conſiſtence, and are grown reſinous. If they be rediſtilled, they recover their former tenuity, leaving behind them a remainder thicker and more reſinous than they themſelves were. This ſecond diſtillation is called the *Rectification* of an Oil.

It muſt be obſerved that an eſſential Oil, combined with an acid ſtrong enough to diſſolve it, immediately becomes as thick and reſinous, in conſequence of this union, as if it had been long expoſed to the air: which proves the conſiſtence an Oil acquires by long keeping to be owing to this, that its lighteſt and leſs acid parts being evaporated, the proportion of its acid to the remainder is ſo increaſed that it produces therein the ſame change as an additional acid mixed with the Oil would have wrought before the evaporation.

This alſo ſhews us that Balſams and Reſins are only eſſential Oils combined with a great proportion of acid, and thereby thickened.

If vegetable ſubſtances, from which no more eſſential Oil can be drawn by the heat of boiling water, be expoſed to a ſtronger heat, they yield an additional quantity of Oil; but it is thicker and heavier than the eſſential Oil. Theſe Oils are black, and have a very diſagreeable burnt ſmell, which hath made them be called *Fetid*, or *Empyreumatic* Oils. They are moreover very acrid.

It muſt be obſerved that, if a vegetable ſubſtance be expoſed to a degree of heat greater than that of boiling water, before the fat or the eſſential Oil is extracted from it, an empyreumatic Oil only will then be obtained; becauſe both the fat and eſſential Oils, when expoſed to the force of fire, are thereby burnt, rendered acrid, acquire a ſmell of the fire, and, in a word, become truly empyreumatic. There is ground to think that an empyreumatic Oil is nothing elſe but an eſſential or fat Oil burnt and ſpoiled by the fire, and that no other Oil beſides theſe two exiſts naturally in vegetables.

Empyreumatic Oils, diſtilled and rectified ſeveral times by a gentle heat, acquire by every diſtillation a greater degree of tenuity, lightneſs, and limpidity. By this means alſo they loſe ſomething of their diſagreeable odour; ſo that they gradually come nearer and nearer to the nature of eſſential Oils: and if the rectifications be often enough repeated, ten or twelve times for inſtance, they become perfectly like thoſe Oils; except that their ſmell will never be ſo agreeable, nor like that of the ſubſtances from which they were obtained.

Fat Oils may alſo be brought by the ſame means to reſemble eſſential Oils: but neither eſſential nor empyreumatic Oils are capable of acquiring the properties of fat Oils.

§. III. *Of* ANIMAL OILS.

DISTILLATION procures us conſiderable quantities of Oil from all the parts of animal bodies, and eſpecially from their fat. This Oil at firſt is not very fluid, and is extremely fetid: but by many rectifications it gradually acquires a great degree of clearneſs and tenuity, and at the ſame time loſes much of its diſagreeable odour. Animal Oils, thus rendered thin and fluid by a great number of rectifications, have the reputation of being an excellent medicine, and a ſpecific in the epilepſy.

CHAP.

CHAP. XII.

Of FERMENTATION *in general.*

BY Fermentation is meant an inteſtine motion, which, ariſing ſpontaneouſly among the inſenſible parts of a body, produces a new diſpoſition and a different combination of thoſe parts.

To excite a Fermentation in a mixt body it is neceſſary firſt, that there be in the compoſition of that mixt a certain proportion of watery, ſaline, oily, and earthy parts: but this proportion is not yet ſufficiently aſcertained. Secondly, it is requiſite that the body to be fermented be placed in a certain degree of temperate heat: for much cold obſtructs fermentation; and too much heat decompoſes bodies. Laſtly, the concurrence of the air is alſo neceſſary to fermentation.

All vegetable and animal ſubſtances are ſuſceptible of Fermentation, becauſe all of them contain in a due proportion the principles above ſpecified. However, many of them want the proper quantity of water, and cannot ferment while they remain in ſuch a ſtate of dryneſs. But it is eaſy to ſupply that defect, and ſo render them very apt to ferment.

With reſpect to minerals properly ſo called (that is, excluding ſuch vegetable and animal ſubſtances as may have lain long buried in the earth) they are not ſubject to any Fermentation; at leaſt that our ſenſes can perceive.

There are three ſorts of Fermentation, diſtinguiſhed from one another by their ſeveral productions. The firſt produces wines and ſpirituous liquors; for which reaſon it is called the *Vinous* or *Spirituous Fermentation:* the reſult of the ſecond is an acid liquor; and therefore it is called the *Acetous Fermentation:* and the third generates an alkaline ſalt; which, however, differs from the alkaline ſalts hitherto treated of, in this reſpect chiefly that, inſtead of being fixed, it is extremely volatile: this laſt ſort takes the name of the *Putrid* or *Putrefactive Fermentation.* We ſhall now conſider theſe three ſorts of Fermentation and their effects a little more particularly.

Theſe three ſorts of Fermentation may take place ſucceſſively in the ſame ſubject; which proves them to be only three different degrees of fermentation, all proceeding from one and the ſame cauſe, rather than three diſtinct fermentations. Theſe degrees of fermentation always follow the order in which we have here placed them.

CHAP. XIII.

Of the SPIRITUOUS FERMENTATION.

THE juices of almoſt all fruits, all ſaccharine vegetable matters, all farinaceous ſeeds and grains of every kind, being diluted with a ſufficient quantity of water, are proper ſubjects of Spirituous Fermentation. If ſuch liquors be expoſed, in veſſels ſlightly ſtopped, to a moderate degree of heat, they begin in ſome time to grow turbid; there ariſes inſenſibly a ſmall commotion among their parts, attended with a hiſſing noiſe; this by little and little increaſes, till the groſſer parts appear, like little ſeeds or grains, moving to and fro, agitated among themſelves, and thrown up to the ſurface. At the ſame time ſome air bubbles riſe, and the liquor acquires a pungent, penetrating ſmell, occaſioned by the very ſubtile vapours which exhale from it.

Theſe vapours have never yet been collected, in order to examine their nature; and they are known only by their noxious effects. They are ſo actively pernicious, that if a man comes raſhly into a cloſe place, where large quantities of liquors are fermenting, he ſuddenly drops down and expires, as if he were knocked on the head.

When theſe ſeveral phenomena begin to go off, it is proper to ſtop the fermentation, if a very ſpirituous liquor be required: for if it be ſuffered to continue longer, the liquor will become acid, and from thence proceed to its laſt ſtage, that is, to putrefaction. This is done by ſtopping the containing veſſels very cloſe, and removing them into a cooler place. Then the impurities precipitate, and ſettling at the bottom leave the liquor clear and tranſparent: and now the palate diſcovers that the ſweet, ſaccharine taſte it had before fermentation is changed to an agreeable pungency which is not acid.

Liquors thus fermented are in general called *Wines*: for though in common life that word properly ſignifies the fermented juice of grapes only, and particular names are given to the fermented juices of other vegetable ſubſtances; as that obtained from Apples is called *Cyder*; that made from malt is called *Beer*: yet in Chymiſtry it is of uſe to have one general term denoting every liquor that has undergone this firſt degree of fermentation.

By diſtillation we draw from Wine an inflammable liquor, of a yellowiſh white colour, light, and of a penetrating, pleaſant ſmell. This liquor is the truly ſpirituous part of the wine, and the product of fermentation. That which comes off in the firſt diſtillation is commonly loaded with much phlegm and ſome oily parts, from which it may be afterwards freed. In this ſtate it goes by the name of *Brandy*; but when freed from theſe heterogeneous matters by repeated diſtillations, it becomes ſtill clearer, lighter, more fragrant, and much more inflammable, and then is called *Spirit of Wine*, and *Rectified Spirit of Wine*, or *Ardent Spirits*, if conſiderably purified. The properties which diſtinguiſh an Ardent Spirit from all other ſubſtances are its being inflammable; its burning and conſuming entirely, without the leaſt appearance of ſmoke or fuliginoſity; its containing no particles reducible to a coal; and its being perfectly miſcible with water. Ardent Spirits are lighter and more volatile than any of the principles of the mixts from which they were produced, and conſequently more ſo than the phlegm, the acid, and the oil of which they themſelves conſiſt. This ariſes from a particular diſpoſition of theſe principles, which are in a ſingular manner attenuated by fermentation, and thereby rendered more ſuſceptible of expanſion and rarefaction.

Ardent ſpirits are ſuppoſed to be the natural ſolvents of oils and oily matters. But it is very remarkable that they diſſolve eſſential oils only, without touching the fat of animals, or the fat oils obtained from vegetables by expreſſion; yet when theſe oils have once undergone the action of fire, they become ſoluble in ſpirit of wine, and even acquire a new degree of ſolubility every time they are diſtilled. It is not ſo with eſſential oils, which can never be rendered more ſoluble in ardent ſpirits than they are at firſt; and are ſo far from acquiring a new degree of ſolubility every time they are diſtilled, that on the contrary they even in ſome meaſure loſe that property by repeated rectifications.

I have taken ſome pains to find out the cauſes of theſe ſingular effects, and the reſult of my enquiries is publiſhed among the Memoirs of the Academy of Sciences for the year 1745. I therein conſider ardent ſpirits as conſiſting of an oil, or at leaſt a phlogiſton, mixed with a portion of water, in which it is rendered ſoluble by means of an acid. This being laid down, I ſhew that the inability of ſpirit of wine to diſſolve ſome oils muſt be imputed to its aqueous part, in which oils are not naturally ſoluble without the intervention of a ſalt; and that the power which this ſpirit exerts in diſſolving other oils with eaſe, ſuch as eſſential oils, muſt in all probability be owing to this, that in theſe oils it meets with the neceſſary ſaline medium, that is, with an acid, which numberleſs experiments ſhew they actually contain.

On the other hand, I there prove that the acid in eſſential oils is ſuperabundant, and in ſome ſort foreign to their nature, or that it is but ſlightly connected with them, and in part deſerts them every time they are diſtilled; which renders them leſs ſoluble after every new rectification: whereas, on the contrary, the fat expreſſed oils in their natural ſtate give not the leaſt ſign of acidity; but the action of fire upon them diſcovers an acid which was not perceivable before. Hence I conjecture that theſe oils contain no more acid than is juſt neceſſary to conſtitute them oils; that this acid is intimately blended with their other component parts; that it is ſo ſheathed and entangled by theſe parts as to be incapable of exerting any of its properties; and that on this account theſe oils in their natural ſtate are not ſoluble in ſpirit of wine: but that the diſpoſition of their parts being gradually changed by the fire, and their acid, being by that means ſet more and more at liberty, at length recovers its properties, and particularly that of rendering the oily parts ſoluble in an aqueous menſtruum: and hence it follows that the fat oils become ſo much the more ſoluble in ſpirit of wine the oftener they are expoſed to the action of fire.

Spirit of wine doth not diſſolve fixed alkalis; or at leaſt it takes up but a very ſmall quantity thereof; and hence ardent ſpirits may be freed from much of their phlegm by means of theſe ſalts thoroughly dried: for as they ſtrongly imbibe moiſture, and have even a greater affinity than ardent ſpirits with water, if a fixed alkali well exſiccated be mixed with ſpirit of wine that is not perfectly dephlegmated, the alkali immediately attracts its ſuperfluous moiſture, and is thereby reſolved into a liquor, which on account of its gravity deſcends to the bottom of the veſſel. The ſpirit of wine, which ſwims a-top, is by thismeans as much dephlegmated, and as dry, as if it had been rectified by ſeveral diſtillations. As it takes up ſome alkaline particles in this operation, it is thereby qualified to diſſolve oily matters with the greater facility. When rectified in this manner it is called *Tartariſed Spirit of Wine.*

Yet ſpirit of wine, even when rectified to an alcohol, is not capable of diſſolving all oily matters. Thoſe named Gums will by no means enter into any ſort of union therewith; but it readily diſſolves moſt of thoſe which are known by the appellation of Reſins. When it has diſſolved a certain proportion of reſinous particles it acquires a greater conſiſtence, and forms what is called a *Spirit-Varniſh*, or a *Drying Varniſh*, becauſe it ſoon dries. This Varniſh is ſubject to be damaged by water. Many ſorts thereof are prepared, differing from each other according to the different reſins employed, or the proportions in which they are uſed. Moſt of theſe Varniſhes are tranſparent and colourleſs.

Such bitumens or reſins as ſpirit of wine will not touch are diſſolved in oils by means of fire, and then form another kind of Varniſh which water does not hurt. Theſe Varniſhes are uſually coloured, and require much longer time to dry than the Spirit-Varniſhes: they are called *Oil-Varniſhes*.

Spirit of wine hath a much greater affinity with water than with oily matters; and therefore if a ſolution of any oil or reſin in ſpirit of wine be mixed with water, the liquor immediately grows turbid, and acquires a whitiſh milky colour, owing entirely to the oily parts being ſeparated from the ſpirituous menſtruum by the acceſſion of water, and too finely divided to appear in their natural form. But if the liquor ſtand ſome time quiet, ſeveral of theſe particles unite together, and gradually acquire a bulk ſufficient to render them very perceptible to the eye.

Acids have an affinity with ſpirit of wine, and may be combined with it. By this union they loſe moſt of their acidity, and on that account are ſaid to be *Dulcified*. But as theſe combinations of acids, eſpecially of the vitriolic acid, with ſpirit of wine furniſh ſome new productions of very ſingular properties, and as an examination thereof may throw much light on the nature of ardent ſpirits, it will not be amiſs to take notice of them in this place, and conſider each of them particularly.

One part of highly concentrated oil of vitriol being mixed with four parts of well dephlegmated ſpirit of wine, there ariſes immediately a conſiderable ebullition and effervescence, attended with great heat, and abundance of vapours, which ſmell pleaſantly, but are hurtful to the lungs. At the ſame time is heard a hiſſing like that produced by a piece of red-hot iron plunged in water. Indeed it is proper to mix the liquors very gradually; for otherwiſe the veſſels in which the operation is performed will be in great danger of breaking.

If the two liquors thus mixed be diſtilled with a very gentle heat, there riſes firſt a ſpirit of wine of a moſt penetrating and grateful odour: when about half thereof is come over, what follows has a quicker and more ſulphureous ſmell, and is alſo more loaded with phlegm. When the liquor begins to boil a little, there comes off a phlegm which ſmells very ſtrong of ſulphur, and grows gradually more acid. On this phlegm floats a ſmall quantity of a very light and very limpid oil. In the ſtill there remains a thick, blackiſh ſubſtance, ſomewhat like a reſin or bitumen. From this ſubſtance may be ſeparated a good deal of a vitriolic but ſulphureous acid. When that is extracted, there remains a black maſs like a charred coal, which being put into a crucible and expoſed to a violent heat leaves a ſmall portion of earth, very fixed, and even vitrifiable.

By rectifying the ardent ſpirit, which came over in diſtilling the abovementioned mixture, a very ſingular liquor is obtained, which differs eſſentially both from oils and from ardent ſpirits, though in certain reſpects it reſembles them both. This liquor is known in Chymiſtry by the name of *Æther*, and its chief properties are as follow.

Æther is lighter, more volatile, and more inflammable, than the moſt highly rectified ſpirit of wine. It quickly flies off when expoſed to the air, and ſuddenly catches fire when any flame approaches it. It burns like ſpirit of wine without the leaſt ſmoke, and conſumes entirely without leaving the ſmalleſt appearance of a coal or of aſhes. It diſſolves oils and oily matters with great eaſe and rapidity. Theſe properties it has in common with an ardent ſpirit. But it reſembles an oil in that it is not miſcible with water; and this makes it eſſentially different from ſpirit of wine, the nature of which is to be miſcible with all aqueous liquors.

Another very ſingular property of Æther is its great affinity with gold, exceeding even that of *aqua regis*. It does not indeed diſſolve gold when in a maſs, and in its metalline form: but if a ſmall quantity of Æther be added to a ſolution of gold in *aqua regis*, and the whole ſhaken together, the gold ſeparates from the *aqua regis*, joins the Æther, and remains diſſolved therein.

The reaſon of all the phenomena above-mentioned, reſulting from the mixture of ſpirit of wine with oil of vitriol, is founded on the great affinity between this acid and water. For if the vitriolic acid be weak, and as it were over-doſed with watery parts, neither oil nor Æther can be obtained by means thereof: but when highly concentrated, it attracts the aqueous parts very powerfully; and therefore being mixed with ſpirit of wine lays hold of moſt of the water contained in it, and even robs it of ſome portion of that which is eſſential to its nature, and neceſſary to conſtitute it ſpirit of wine: whence it comes to paſs that a certain quantity of the oily particles in its compoſition being ſeparated from the watery particles, and ſo brought nearer to each other, they unite and aſſume their natural form; and thus the oil that ſwims at top of the ſulphureous phlegm is produced.

The vitriolic acid moreover thickens and even burns ſome of this oil; and hence comes the bituminous reſiduum left at the bottom of the ſtill, which looks like the reſult of a vitriolic acid combined with common oil. Laſtly, the vitriolic acid becomes ſulphureous, as it always doth when united with oily matters, and alſo very aqueous, on account of the quantity of phlegm which it attracts from the ſpirit of wine.

Æther may be conſidered as a ſpirit of wine exceedingly dephlegmated, even to ſuch a degree that its nature is thereby changed; ſo that the few aqueous particles left in it are not ſufficient to diſſolve the oily particles and keep them aſunder; which therefore being now much nearer to one another than in common ſpirit of wine, the liquor hath loſt its property of being miſcible with water.

Spirit of nitre well dephlegmated, and combined with ſpirit of wine, preſents likewiſe ſome very ſingular appearances.

Firſt, in the very inſtant of its mixture with ſpirit of wine it produces a greater and more violent efferveſcence than the vitriolic acid occaſions.

Secondly, this mixture, without the help of diſtillation, and only by ſtopping the bottle in which the liquors are contained, affords a ſort of Æther, produced probably by the vapours which aſcend from, and ſwim at top of the mixture. This is a very ſingular liquor. Dr. Navier was the firſt that took notice of it, and gave a deſcription thereof, which may be ſeen in the Memoirs of the Academy of Sciences.

Thirdly, ſome authors pretend that by diſtilling the mixture under conſideration an oil is obtained greatly reſembling that which, as we obſerved above, riſes from ſpirit of wine combined with the vitriolic acid: others again deny this. For my part, I believe the thing depends on the different concentration of the ſpirit of nitre, as well as on the quality of the ſpirit of wine, which is ſometimes more ſometimes leſs oily.

Fourthly, the two liquors we are ſpeaking of, being intimately mixed by diſtillation, form a liquor ſlightly acid, uſed in medicine, and known by the name of *Sweet* or *Dulcified Spirit of Nitre*; a very proper name, ſeeing the nitrous acid, by uniting with the ſpirit of wine, actually loſes almoſt all its acidity and corroſive quality.

Fifthly and laſtly, when the diſtillation is finiſhed, there remains in the bottom of the veſſel a thick, blackiſh ſubſtance, nearly reſembling that which is found after diſtilling oil of vitriol and ſpirit of wine.

Spirit of ſalt hath likewiſe been combined with ſpirit of wine; but it does not unite therewith ſo eaſily or ſo intimately as the two acids abovementioned. To mix them thoroughly, the ſpirit of ſalt muſt be highly concentrated, and ſmoking, and moreover the aſſiſtance of the ſtill muſt be called in. Some authors pretend that from this mixture alſo a ſmall quantity of oil may be obtained; which probably happens when the liquors have the qualities above ſpecified. The marine acid likewiſe, by uniting with ſpirit of wine, loſes moſt of its acidity; on which account it is in like manner called *Sweet* or *Dulcified Spirit of Salt*. A thick reſiduum is alſo found here after diſtillation.

CHAP. XV.

Of the ACETOUS FERMENTATION.

BESIDES an ardent ſpirit, wine affords a great deal of water, oil, earth, and a ſort of acid which ſhall be conſidered preſently. When the ſpirituous part is ſeparated from theſe other matters, they undergo no further change. But if all the conſtituent parts of wine remain combined together, then, after ſome time, ſhorter or longer as the degree of heat in which the wine ſtands is greater or leſs, the fermentation begins afreſh, or rather arrives at its ſecond ſtage. The liquor once more grows turbid, a new inteſtine motion ariſes, and after ſome days it is found changed into an acid; which, however, is very different from thoſe hitherto treated of. The liquor then takes the name of *Vinegar*. The acetous fermentation differs from the ſpirituous, not only in its effect, but alſo in ſeveral of its concomitant circumſtances. Moderate motion is of ſervice to this, whereas it obſtructs the ſpirituous; and it is attended with much more warmth than the ſpirituous. The vapours it produces are not noxious, like thoſe of fermenting wine. Laſtly, Vinegar depoſites no tartar, even when the wine employed in this operation is quite new, and hath not had time to diſcharge its tartar: inſtead of tartar Vinegar depoſites a viſcid matter which is very apt to putrify.

It muſt be obſerved that wine is not the only ſubſtance that is ſuſceptible of the acetous fermentation: for ſeveral vegetable and even animal matters, which are not ſubject to the ſpirituous fermentation, turn ſour before they putrify. But as vinous liquors poſſeſs in a very eminent degree the property of being ſuſceptible of the acetous fermentation, and likewiſe of producing the ſtrongeſt acids that can reſult from ſuch fermentation, their acid ſhall be more particularly conſidered in this place.

§. I. *Of* VINEGAR.

IF wine, which has gone through this ſecond ſtage of fermentation, be diſtilled, inſtead of an ardent ſpirit, only an acid liquor is obtained, which is called *Diſtilled Vinegar*.

This acid has the ſame properties as the mineral acids of which we have already treated; that is, it unites with alkaline ſalts, abſorbent earths, and metallic ſubſtances, and therewith forms neutral ſaline combinations.

Its affinity with theſe ſubſtances obſerves the ſame order as that obſerved by the mineral acids with regard to the ſame ſubſtances; but in general it is weaker; that is, any mineral acid is capable of expelling the acid of Vinegar out of all matters with which it is united.

Vinegar hath likewiſe a greater affinity than ſulphur with alkalis: whence it follows that it is capable of decompounding that combination of ſulphur with an alkali called Liver of Sulphur, and of precipitating the ſulphur it contains.

The acid of Vinegar is always clogged with a certain proportion of oily parts, which greatly weaken it, and deprive it of much of its activity; and for this reaſon it is not near ſo ſtrong as the mineral acids, which are not entangled with any oil. By diſtillation, indeed, it may be freed from this oil, and at the ſame time from the great quantity of water which in a manner ſuffocates it, and by that means may be brought much nearer to the nature of the mineral acids: but this attempt hath not yet been proſecuted with the aſſiduity it deſerves. Beſides diſtillation, there is another way of freeing Vinegar from a good deal of its phlegm; and that is, by expoſing it to a hard froſt, which readily congeals the watery part into ice, while the acid retains its fluidity.

Vinegar, ſaturated with a fixed alkali, forms a neutral oily ſalt, of a dark colour, which is ſemi-volatile, melts with a very gentle heat, flames when thrown upon burning coals, and diſſolves in ſpirit of wine, of which, however, it requires ſix parts to complete the ſolution. This ſolution being evaporated to dryneſs leaves a matter in the form of leaves lying on each other; on which account it hath obtained the name of *Terra Foliata.* The ſame foliated matter will be obtained, though the ſalt be not previouſly diſſolved in ſpirit of wine; but not ſo readily. This ſalt is alſo called *Regenerated Tartar.* Under the head of Tartar we ſhall ſee the reaſon of theſe different appellations. Regenerated Tartar is alſo in ſome degree capable of cryſtallizing: for this purpoſe a ſolution thereof in water muſt be ſlowly evaporated to the conſiſtence of a ſyrup, and then ſuffered to ſtand quiet in a cool place; by which means it will ſhoot into cluſters of cryſtals, lying one upon another, not unlike the feathers on a quill.

With Vinegar and ſeveral abſorbent earths, ſuch as calcined pearls, coral, ſhells of fiſh, &c. are alſo formed neutral ſaline compounds, each of which takes the name of the particular earth employed in its compoſition.

Vinegar perfectly diſſolves Lead, and converts it to a neutral metallic ſalt, which ſhoots into cryſtals, and has a ſweet ſaccharine taſte. This compound is called *Sugar of Lead*, or *Sal Saturni*.

If Lead be expoſed to the bare vapour of Vinegar, it will be thereby corroded, calcined, and converted into a white matter much uſed in painting, and known by the name of *Ceruſe*; or, when it is finer than ordinary, *White Lead*.

Vinegar corrodes Copper likewiſe, and converts it into a beautiful green ruſt, which alſo is uſed in painting, and diſtinguiſhed by the name of *Verdegris*. However, Vinegar is not commonly employed to make Verdegris: for this purpoſe they uſe wine, or the rape of wine, from which fire extricates an acid analogous to that of Vinegar.

In treating of the ſeveral ſubſtances which conſtitute wine we mentioned an acid matter, but did not then enter into a particular examination thereof; becauſe as that matter greatly reſembles the acid of Vinegar, we thought it more proper to defer the conſideration of its properties till we had treated of the acetous fermentation, and its effects.

§. II. *Of* TARTAR.

THIS ſubſtance is a ſaline compound, conſiſting of earthy, oily, and eſpecially acid parts. It is found in the form of cruſts, adhering to the inner ſides of veſſels in which wines have ſtood for ſome time, particularly acid wines, ſuch as thoſe of Germany.

Tartar derives its origin from the ſuperabundant quantity of acid contained in the juice of the grape. This ſuperfluous acid, being more than is requiſite to conſtitute the ardent ſpirit, unites with ſome of the oil and earth contained in the fermented liquor, and forms a kind of ſalt; which for ſome time continues ſuſpended in that liquor, but, when the wine ſtands undiſturbed in a cool place, is depoſited, as hath been ſaid, on the ſides of the caſk.

Tartar in this ſtate contains many earthy parts, which are ſuperfluous, and foreign to its nature. From theſe it may be freed by boiling it repeatedly with a ſort of earth found in the neighbourhood of Montpellier, as may be ſeen in the Memoirs of the Academy of Sciences.

When it is purified there appears on the ſurface of the liquor a ſort of white cryſtalline pellicle, which is ſkimmed off as it forms. This matter is called *Cream of Tartar.* The ſame liquor which produces this Cream, and in which the purified Tartar is diſſolved, being ſet to cool yields a great number of white ſemi-tranſparent cryſtals, which are called *Cryſtals of Tartar.* The Cream and the Cryſtals of Tartar are therefore no other than purified Tartar, and differ from each other in their form only.

Though the Cryſtals of Tartar have every appearance of a neutral ſalt, yet they are far from being ſuch; for they have all the properties of a true acid, which ſcarce differs from that of vinegar, except that it contains leſs water, and more earth and oil; to which it owes its ſolid form, as well as its property of not being ſoluble in water without much difficulty: for a very great quantity of water is requiſite to keep the Cryſtals of Tartar in ſolution; and it muſt moreover be boiling hot; otherwiſe as ſoon as it cools moſt of the

Tartar diſſolved in it ſeparates from the liquor, and falls to the bottom in the form of a white powder.

Tartar is decompoſed by calcination in the open fire. All its oily parts are conſumed or diſſipated in ſmoke, together with moſt of its acid. The other part of its acid, uniting intimately with its earth, forms a very ſtrong and very pure fixed alkali, called *Salt of Tartar*.

It will be ſhewn in its proper place that almoſt every vegetable matter, as well as Tartar, leaves a fixed alkali in its aſhes: yet Tartar has theſe peculiar properties; firſt, it aſſumes an alkaline character even when burnt or calcined in cloſe veſſels; whereas other ſubſtances acquire it only by being burnt in the open air; ſecondly, the alkali of Tartar is ſtronger and more ſaline than almoſt any that is obtained from other matters.

This alkali, when thoroughly calcined, powerfully attracts the moiſture of the air, and melts into an unctuous alkaline liquor, improperly called *Oil of Tartar per deliquium*. This is the alkali generally uſed in making the *Terra foliata*, mentioned under the head of Vinegar; for which reaſon this combination is called *Terra Foliata Tartari*, a name ſuitable enough. But the ſame cannot be ſaid of the other name, *Regenerated Tartar*, which is alſo given it. 'Tis true that on this occaſion an oily acid is reſtored to the earth of the Tartar, analogous to that of which the fire had deprived it: but the compound thence reſulting is a neutral ſalt which very readily diſſolves in water; whereas Tartar is manifeſtly acid, and not ſoluble, or at leaſt hardly ſoluble, in water.

Cryſtals of Tartar combined with alkali of Tartar produce a great efferveſcence while they are mixing, as all acids uſually do; and if the combination be brought exactly up to the point of ſaturation, a per-a perfectly neutral ſalt is formed, which ſhoots into cryſtals, and eaſily diſſolves in water; and this hath procured it the name of *Soluble Tartar*. It is alſo called the *Vegetable Salt*, as being obtained from vegetables only; and again, *Tartariſed Tartar*, becauſe it conſiſts of the acid and the alkali of Tartar combined together.

Cryſtals of Tartar combined with alkalis procured from the aſhes of ſea-weeds, ſuch as Soda, which alkalis reſemble the baſis of ſea-ſalt, form likewiſe a neutral ſalt, which cryſtallizes well, and diſſolves eaſily in water. This ſalt is another ſort of ſoluble Tartar. It is called *Saignette*'s *Salt*, from the inventor's name.

Both the Vegetable Salt and Saignette's Salt are gently purgative ſoaps, and much uſed in Medicine.

Tartar likewiſe diſſolves the abſorbent earths, as lime, chalk, &c. and with them forms neutral ſalts which are ſoluble in water*. It even attacks metallic bodies, and when combined with them becomes ſoluble. A ſoluble Tartar for medical uſe is prepared with Cryſtals of Tartar and Iron: the metallic ſalt thereby produced hath the name of *Chalybeated ſoluble Tartar*. This ſalt attracts the moiſture of the air, and is one of thoſe which do not cryſtallize.

Cryſtallized Tartar acts alſo upon ſeveral other metallic ſubſtances: for inſtance, it diſſolves the Regulus, Liver, and Glaſs of Antimony; and thence acquires an emetic quality: it is then called *Stibiated* or *Emetic Tartar*. It likewiſe diſſolves Lead, and therewith forms a ſalt which, in the figure of its cryſtals, reſembles Tartariſed Tartar.

It is very extraordinary that Tartar, which of itſelf is not ſoluble in water, ſhould be ſoluble therein when become a neutral ſalt by uniting either with alkalis or with abſorbent earths, or even with metals. With reſpect to alkalis, indeed, it may be urged that, having themſelves a great affinity with water, they communicate to Tartar ſome of that facility with which they naturally unite therewith: but the ſame cannot be alledged concerning abſorbent earths, and metallic ſubſtances, which water diſſolves not at all, or at leaſt with great difficulty, and in ſmall quantity. This effect, therefore, muſt be attributed wholly to ſome change in the diſpoſition of its parts which is to us unknown.

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* See Mr. Duhamel's Eſſays on this ſubject in the Memoirs of the Academy of Sciences.

All the ſoluble Tartars are eaſily decompounded by expoſing them to a certain degree of heat. In diſtillation they yield the ſame principles which are obtained from Tartar; and what remains fixed in the fire, after they are thoroughly burnt, is a compound of the alkali which Tartar naturally produces, and of the alkaline or metallic ſubſtance with which it was converted into a neutral ſalt.

As Cryſtal of Tartar is the weakeſt of all acids, on account of the oily and earthy matters with which it is combined, ſoluble Tartars are decompounded by all the acids; by any of which cryſtal of Tartar may be ſeparated from the ſubſtance that ſerves it for a baſis and renders it a neutral ſalt.

The other acids which are procured from vegetables, and even thoſe which are obtainable from ſome animal ſubſtances, may all be referred to and compared with either Vinegar or Tartar, according to the quantities of oil or earth with which they are combined.

After all, theſe acids have not yet been thoroughly examined. There is great reaſon to think that they are no other than the mineral acids, which in paſſing through the bodies of vegetables, and even of animals, undergo a conſiderable change, eſpecially by contracting an union with oily matters.

For, as we ſaid before in treating of Vinegar, by freeing them from their oil they are brought very near to the nature of mineral acids: and ſo likewiſe the mineral acids acquire many of the properties of vegetable acids by being combined with oils.

CHAP. XV.

Of the PUTRID FERMENTATION, *or* PUTREFACTION.

EVERY body which hath gone through the two ſtages of fermentation above deſcribed, that is, the ſpirituous and the acetous fermentation, being left to itſelf in a due degree of warmth, which varies according to the ſubject, advances to the laſt ſtage of fermentation; that is, to putrefaction.

It is proper to obſerve, before we go any further, that the reverſe of this propoſition is not true; that is, it is not neceſſary that a body ſhould ſucceſſively paſs through the ſpirituous and the acetous fermentation, before it can arrive at the putrid; but that, as certain ſubſtances fall into the acetous without having gone through the ſpirituous fermentation, ſo others begin to putrify without having undergone either the ſpirituous or the acetous fermentation; of which laſt kind are, for inſtance, moſt animal ſubſtances. When therefore we repreſented theſe three ſorts of fermentation as three different degrees or ſtages of one and the ſame fermentation, we ſuppoſed it to be excited in a body ſuſceptible of fermentation in its full extent.

However, there is ſtill room to think that every ſubſtance which is capable of fermenting always paſſes neceſſarily through theſe three different ſtages; but that the ſubſtances moſt diſpoſed thereto paſs with ſuch rapidity through the firſt, and even the ſecond, that they arrive at the third before our ſenſes can perceive the leaſt ſigns of either of the two former. This opinion is not deſtitute of probability; yet it is not ſupported by proofs ſufficiently ſtrong and numerous to compell our aſſent.

When a body is in a putrefying ſtate it is eaſy to diſcover, (as in the two ſorts of fermentation already treated of,) by the vapours which riſe from it, by the opacity which invades it, if a pellucid liquor, and frequently even by a greater degree of heat than is found in the two other ſorts of fermentation, that an inteſtine motion is begun among its conſtituent parts, which laſts till the whole be entirely putrefied.

The effect of this inteſtine motion is in this, as in the two other ſorts of fermentation, to break the union, and change the diſpoſition, of the particles conſtituting the body in which it is excited, and to produce a new combination. This is brought about by a mechaniſm to which we are ſtrangers, and concerning which nothing beyond conjectures can be advanced: but theſe we neglect, reſolving to keep wholly to facts, as the only things in Natural Philoſophy that are poſitively certain.

If, then, we examine a ſubſtance that has undergone putrefaction, we ſhall ſoon perceive that it contains a principle which did not exiſt in it before. If this ſubſtance be diſtilled, there riſes firſt, by means of a very gentle heat, a ſaline matter which is exceedingly volatile, and affects the organ of ſmelling briſkly and diſagreeably. Nor is the aid of diſtillation neceſſary to diſcover the preſence of this product of putrefaction; it readily manifeſts itſelf in moſt ſubſtances where it exiſts, as any one may ſoon be convinced by obſerving the different ſmell of freſh and of putrefied urine; for the latter not only affects the noſe, but even makes the eyes ſmart, and irritates them ſo as to draw tears from them in abundance.

This ſaline principle which is the product of putrefaction, when ſeparated from the other principles of the body which affords it, and collected by itſelf, appears either in the form of a liquor, or in that of a concrete ſalt, according to the different methods uſed to obtain it. In the former ſtate it is called a *Volatile Urinous Spirit*; and in the latter a *Volatile Urinous Salt*. The qualification of urinous is given it, becauſe, as was ſaid, a great deal thereof is generated in putrefied urine, to which it communicates its ſmell. It goes alſo by the general name of a *Volatile Alkali*, whether in a concrete or in a liquid form. The enumeration of its properties will ſhew why it is called an Alkali.

Volatile Alkalis, from whatever ſubſtance obtained, are all alike, and have all the ſame properties; differing only according to their degrees of purity. The Volatile Alkali, as well as the Fixed, conſiſts of a certain quantity of acid combined with and entangled by a portion of the earth of the mixt body from which it was obtained; and on that account it has many properties like thoſe of a Fixed Alkali. But there is moreover in its compoſition a conſiderable quantity of a fat or oily matter, of which there is none in a Fixed Alkali; and on this account again there is a great difference between them. Thus the Volatility of the Alkali produced by putrefaction, which is the principal difference between it and the other kind of Alkali whoſe nature it is to be Fixed, muſt be attributed to the portion of oil which it contains: for there is a certain method of volatilizing Fixed Alkalis by means of a fatty ſubſtance.

Volatile Alkalis have a great affinity with acids, unite therewith rapidly and with ebullition, and form with them neutral ſalts, which ſhoot into cryſtals, but differ from one another according to the kind of acid employed in the combination.

The neutral ſalts which have a Volatile Alkali for their baſis are in general called *Ammoniacal Salts.* That whoſe acid is the acid of ſea-ſalt is called *Sal Ammoniac.* As this was the firſt known, it gave name to all the reſt. Great quantities of this ſalt are made in Egypt, and thence brought to us. They ſublime it from the ſoot of cow's-dung, which is the fewel of that country, and contains ſea-ſalt, together with a Volatile Alkali, or at leaſt the materials proper for forming it; and conſequently all ~~the~~ ingredients that enter into the compoſition of Sal Ammoniac. See the Memoirs of the Academy of Sciences.

The neutral ſalts formed by combining the acids of nitre and of vitriol with a Volatile Alkali are called, after their acids, *Nitrous Sal Ammoniac* and *Vitriolic Sal Ammoniac*: the latter, from the name of its inventor, is alſo called Glauber's *Secret Sal Ammoniac.*

A Volatile Alkali, then, has the ſame property as a fixed Alkali with regard to acids; yet they differ in this, that the affinity of the former with acids is weaker than that of the latter: and hence it follows that any Sal Ammoniac may be decompounded by a Fixed Alkali, which will lay hold of the acid, and diſcharge the Volatile Alkali.

A Volatile Alkali will decompound any neutral ſalt which has not a Fixed Alkali for its baſis; that is, all ſuch as conſiſt of an acid combined with an abſorbent earth or a metallic ſubſtance. By joining with the acids in which they are diſſolved, it diſengages the earths or metallic ſubſtances, takes their place, and in conjunction with their acids forms Ammoniac Salts.

Hence it might be concluded that, of all ſubſtances, next to the Phlogiſton and the Fixed Alkalis, Volatile Alkalis have the greateſt affinity with acids in general. Yet there is ſome difficulty in this matter: for abſorbent earths and ſeveral metallic ſubſtances are alſo capable of decompounding Ammoniacal Salts, diſcharging their Volatile Alkali, and forming new compounds by uniting with their acids. This might induce us to think that theſe ſubſtances have nearly the ſame affinity with acids.

But it is proper to obſerve, that a Volatile Alkali decompounds ſuch neutral ſalts as have for their baſis either an abſorbent earth or a metallic ſubſtance, without the aid of fire; whereas abſorbent earths or metallic ſubſtances will not decompound an Ammoniacal Salt, unleſs they be aſſiſted by a certain degree of heat.

Now as all theſe matters are extremely fixed, at leaſt in compariſon with a Volatile Alkali, they have the advantage of being able to reſiſt the force of fire, and ſo of acting in conjunction therewith; and fire greatly promotes the natural action of ſubſtances upon one another: whereas the Volatile Alkali in the Ammoniacal Salt, being unable to abide the force of fire, is compelled to deſert its acid; and that ſo much the more quickly, as its affinity therewith is conſiderably weakened by the preſence of an earthy or metallic ſubſtance, both of which have a great affinity with acids.

Theſe conſiderations oblige us to conclude, that Volatile Alkalis have a ſomewhat greater affinity, than abſorbent earths and metallic ſubſtances, with acids.

Ammoniacal Salts projected upon nitre in fuſion make it detonate; and the Nitrous Sal Ammoniac detonates by itſelf, without the addition of any inflammable matter. This ſingular effect evidently demonſtrates the exiſtence of an oily matter in Volatile Alkalis; for it is certain that nitre will never deflagrate without the concurrence, and even the immediate contact, of ſome combuſtible matter.

This oily ſubſtance is often found combined with Volatile Alkalis in ſuch a large proportion as to diſguiſe it, in ſome meaſure, and render it exceeding foul. The ſalt may be freed from its ſuperfluous oil by repeated ſublimations; and particularly by ſubliming it from abſorbent earths, which readily drink up oils. This is called the *Rectification* of a Volatile Alkali. The ſalt, which before was of a yellowiſh or dirty colour, by being thus rectified becomes very white, and acquires an odour more pungent and leſs fetid than it had at firſt, that is, when obtained by one ſingle diſtillation from a putrid ſubſtance.

It is proper to obſerve that the rectification of a Volatile Alkali muſt not be carried too far, or repeated too often; for by that means it may be entirely decompoſed at length; and particularly if an abſorbent earth, and eſpecially chalk, be employed for that purpoſe, the ſalt may be converted into an oil, an earth, and water.

Volatile Alkalis act upon ſeveral metallic ſubſtances, and particularly on copper; of which they make a moſt beautiful blue ſolution. On this property depends a pretty ſingular effect, which happens ſometimes when we attempt by means of a Volatile Alkali to ſeparate copper from any acid with which it is combined. Inſtead of ſeeing the liquor grow turbid, and the metal fall, both which generally happen when any Alkali whatever is mixed with a metallic ſolution, we are ſurpriſed to obſerve the ſolution of copper, upon adding a Volatile Alkali, retain its limpidity, and let fall no precipitate; or at leaſt if the liquor does grow turbid, it remains ſo but for a moment, and inſtantly recovers its tranſparency.

This is occaſioned by adding ſuch a quantity of Volatile Alkali as is more than ſufficient fully to ſaturate the acid of the ſolution, and conſiderable enough to diſſolve all the copper as faſt as it is ſeparated from the acid. On this occaſion the liquor acquires a deeper blue than it had before; which ariſes from the property which Volatile Alkalis have of giving this metal, when combined with them, a fuller blue than any other ſolvent can: hence we have a touchſtone to diſcover copper wherever it is; for let the quantity of this metal combined with other metals be ever ſo ſmall, a Volatile Alkali never fails to diſcover it, by making it appear of a blue colour.

Though a Volatile Alkali be conſtantly the reſult of putrefaction, yet it muſt not therefore be imagined that none can be produced by any other means; on the contrary, moſt of thoſe which contain the ingredients neceſſary to form it yield no inconſiderable quantity thereof in diſtillation. Tartar, for example, which by being burnt in an open fire is converted, as was ſhewn, into a Fixed Alkali, yields a Volatile Alkali when it is decompoſed in cloſe veſſels; that is, when it is diſtilled: becauſe in this latter caſe the oily part is not diſſipated or burnt, as it is by calcination in a naked fire, but has time to unite with ſome of the earth and acid of the mixt, in ſuch a manner as to form a true Volatile Alkali.

To prove that on this occaſion, as well as on all others, where unputrefied bodies yield a Volatile Alkali, this ſalt is the product of the fire, we need only obſerve, that in theſe diſtillations it never riſes till after ſome part of the phlegm, of the acid, and even of the thick oil of the mixt, is come over;

which never is the caſe when it is formed beforehand in the body which is the ſubject of the operation, as it is in thoſe which have undergone putrefaction: for this ſalt, being much lighter and more volatile than thoſe other ſubſtances, riſes of courſe before them in diſtillation.

CHAP. XVI.

A General View of CHYMICAL DECOMPOSITION.

THOUGH we have conſidered all the ſubſtances which enter into the compoſition of Vegetables, Animals, and Minerals, whether as primary or as ſecondary principles, it will not be improper to ſhew in what order we obtain theſe principles from the ſeveral mixts; and eſpecially from Vegetables and Animals, becauſe they are much more complicated than Minerals. This is called *Analyſing* a compound.

The method moſt commonly taken to decompoſe bodies is by applying to them ſucceſſive degrees of heat, from the gentleſt to the moſt violent, in appropriated veſſels, ſo contrived as to collect what exhales from them. By this means the principles are gradually ſeparated from each other; the moſt volatile riſe firſt, and the reſt follow in order, as they come to be acted on by the proper degree of heat: and this is called *Diſtillation.*

But it being obſerved that fire, applied to the decompoſition of bodies, moſt commonly alters their ſecondary principles very ſenſibly, by combining them in a different manner with each other, or even partly decompoſing them, and reducing them to their primitive principles; other means have been uſed to ſeparate thoſe principles without the help of fire.

With this view the mixts to be decompoſed are forcibly compreſſed, in order to ſqueeze out of them all ſuch parts of their ſubſtance as they will by this means part with; or elſe thoſe mixts are for a long time triturated, either along with water, which carries off all their ſaline and ſaponaceous contents; or with ſolvents, ſuch as ardent ſpirits, capable of taking up every thing in them that is of an oily or reſinous nature.

We ſhall here give a ſuccinct account of the effects of theſe different methods, as applied to the principal ſubſtances among Vegetables and Animals, and likewiſe to ſome Minerals.

§. I. *The* ANALYSIS *of* VEGETABLE SUBSTANCES.

A vaſt many vegetable ſubſtances, ſuch as kernels and ſeeds, yield by ſtrong compreſſion great quantities of mild, fat, unctuous Oils, which are not ſoluble in ardent ſpirits: theſe are what we called *Expreſſed Oils*. They are alſo ſometimes called *Fat Oils*, on account of their unctuouſneſs, in which they exceed all other ſorts of Oil. As theſe Oils are obtained without the aid of fire, it is certain that they exiſted in the mixt juſt as we ſee them, and that they are not in the leaſt altered; which could not have been the caſe had they been obtained by diſtillation: for that never produces any Oils but ſuch as are acrid and ſoluble in ſpirit of wine.

Some vegetable matters, ſuch as the rind of citrons, lemons, oranges, &c. alſo yield, only by being ſqueezed between the fingers, a great deal of Oil. This ſpirts out in fine ſmall jets, which being received upon any poliſhed ſurface, ſuch as a looking-glaſs, run together and form a liquor that is a real Oil.

But it muſt be carefully noted that this ſort of Oil, though obtained by expreſſion only, is nevertheleſs very different from the Oils mentioned before to which the title of *Expreſſed Oils* peculiarly belongs: for this is far lighter and thinner; moreover, it retains the perfect odour of the fruit which yields it, and is ſoluble in ſpirit of wine; in a word, it is a true eſſential Oil, but abounds ſo in the fruits which produce it, and is lodged therein in ſuch a manner, occupying a vaſt number of little cells provided in the peel for its reception, that a very ſlight preſſure diſcharges it; which is not the caſe with many other vegetables that contain an eſſential Oil.

Succulent and green plants yield by compreſſion a great deal of liquor or juice, which conſiſts of moſt of the phlegm, of the ſalts, and a ſmall portion of the oil and earth of the plant. Theſe juices, being ſet in a cool place for ſome time, depoſite ſaline cryſtals, which are a combination of the acid of the plant with part of its oil and earth, wherein the acid is always predominant. Theſe ſalts, as is evident from the deſcription here given, bear a great reſemblance to the tartar of wine treated of above. They are called *Eſſential Salts*; ſo that Tartar might likewiſe be called the *Eſſential Salt of Wine.*

Dried plants, and ſuch as are of a ligneous, or acid nature, require to be long triturated with water, before they will yield their eſſential ſalts. Trituration with water is an excellent way to get out of them all their ſaline and ſaponaceous contents.

A vegetable matter that is very oily yields its eſſential ſalt with much difficulty, if at all; becauſe the exceſſive quantity of oil entangles the ſalt ſo that it cannot extricate itſelf or ſhoot into cryſtals. Mr. Gerike, in his *Principles of Chymiſtry*, ſays, that if part of the oil of a plant be extracted by ſpirit of wine, its eſſential ſalt may be afterwards obtained with more eaſe and in greater quantity. This muſt be a very good method for ſuch plants as have an exceſſive proportion of eſſential oil; but will not ſucceed if the eſſential ſalt be hindered from cryſtalizing by a redundancy of fat oil, becauſe fat oils are not ſoluble in ſpirit of wine.

Eſſential Salts are among thoſe ſubſtances which cannot be extracted from mixts by diſtillation; for the firſt impreſſion of fire decompoſes them.

Though the acid which predominates in the Eſſential Salts of plants, be moſt commonly analogous to the vegetable acid, properly ſo called, that is, to the acid of vinegar and tartar, which is probably no other than the vitriolic acid diſguiſed; yet it ſometimes differs therefrom, and ſomewhat reſembles the nitrous or the marine acid. This depends on the places where the plants grow which produce theſe ſalts: if they be ſubmarine plants, their acid is akin to the acid of ſea-ſalt; if on the contrary they grow upon walls, or in nitrous grounds, their acid is like that of nitre. Sometimes one and the ſame plant contains ſalts analogous to all the three mineral acids; which ſhews that the vegetable acids are no other than the mineral acids variouſly changed by circulating through plants.

Liquors containing the Eſſential Salts of plants being evaporated by a gentle heat to the conſiſtence of honey, or even further, are called *Extracts*. Hence it is plain, that an Extract is nothing but the Eſſential Salt of a plant, combined with ſome particles of its oil and earth, that remained ſuſpended in the liquor, and are now incorporated by evaporation.

Extracts of plants are alſo prepared by boiling them long in water, and then evaporating ſome part it. But theſe Extracts are of inferior virtue; becauſe the fire diſſipates many of the oily and ſaline parts.

EMULSIONS.

Subſtances which abound much in Oil, being bruiſed and triturated with water for ſome time, afford a liquor of an opaque dead-white colour like milk. This liquor conſiſts of ſuch juices as the water is capable of diſſolving, together with a portion of the oil, which being naturally indiſſoluble in water, is only divided and diſperſed in the liquor, the limpidity whereof is by that means deſtroyed. This ſort of oily liquor, in which the oil is only divided, not diſſolved, is called an *Emulſion*. The oily particles in Emulſions ſpontaneouſly ſeparate from the water, when left at reſt, and uniting into greater maſſes riſe, on account of their lightneſs, to the ſurface of the liquor, which by that means recovers a degree of tranſparency.

If vegetables abounding in eſſential oils and reſins be digeſted in ſpirit of wine, the menſtruum takes up theſe oily matters, as being capable of diſſolving them; and they may afterwards be eaſily ſeparated from it by the affuſion of water. The water, with which ſpirit of wine has a greater affinity than with oily matters, ſeparates them by this means from their ſolvent, agreeably to the common laws of affinities.

Without the help of fire ſcarce any thing, beſides the ſubſtances already mentioned, can be obtained from a plant: but by the means of diſtillation we are enabled to analyſe them more completely. In proſecuting this method of extracting from a plant the ſeveral principles of which it conſiſts, the following order is to be obſerved.

A plant being expoſed to a very gentle heat, in a diſtilling veſſel ſet in the *balneum mariæ*, yields a water which retains the perfect ſmell thereof. Some Chymiſts, and particularly the illuſtrious Boerhaave, have called this liquor the *Spiritus Rector*. The nature of this odoriferous part of plants is not yet thoroughly known; becauſe it is ſo very volatile that it is difficult to ſubject it to the experiments neceſſary for diſcovering all its properties.

If inſtead of diſtilling the plant in the *balneum mariæ*, it be diſtilled over a naked fire, with the precaution of putting a certain quantity of water into the diſtilling veſſel along with it, to prevent its ſuffering a greater heat than that of boiling water, all the eſſential oil contained in that plant will riſe together with that water, and with the ſame degree of heat.

On this occaſion it muſt be obſerved that no eſſential oil can be obtained from a plant after the *Spiritus Rector* hath been drawn off; which gives ground to think that the volatility of theſe oils is owing to that ſpirit.

The heat of boiling water is alſo ſufficient to ſeparate from vegetable matters the fat oils which they contain: that, however, is to be done by the way of decoction only, and not by diſtillation; becauſe though theſe oils will ſwim on water, yet they will not riſe in vapours without a greater degree of heat.

When the eſſential oil is come over, if the plant be expoſed to a naked fire, without the addition of water, and the heat be increaſed a little, a phlegm will riſe that gradually grows acid; after which, if the heat be increaſed as occaſion requires, there will come over a thicker and heavier oil; from ſome a volatile alkali; and laſt of all, a very thick, black, empyreumatic oil.

When nothing more riſes with the ſtrongeſt degree of heat, there remains of the plant a mere coal only, called the *Caput mortuum*, or *Terra damnata*. This coal when burnt falls into aſhes, which being lixiviated with water, give a fixed alkali.

It is obſervable that in the diſtillation of plants which yield an acid and a volatile alkali, theſe two ſalts are often found quite diſtinct and ſeparate in the ſame receiver; which ſeems very extraordinary, conſidering that they are naturally diſpoſed to unite, and have a great affinity with one another. The reaſon of this phenomenon is that they are both combined with much oil, which embarraſſes them ſo that they cannot unite to form a neutral ſalt, as they would not fail to do were it not for that impediment.

All vegetables, except ſuch as yield a great deal of volatile alkali, being burnt in an open fire, and ſo as to flame, leave in their aſhes a large quantity of an acrid, cauſtic, fixed alkali. But if care be taken to ſmother them, ſo as to prevent their flaming while they burn, by covering them with ſomething that may continually beat down again what exhales, the ſalt obtained from their aſhes will be much leſs acrid and cauſtic; the cauſe whereof is, that ſome part of the acid and oil of the plant being detained in the burning, and ſtopped from being diſſipated by the fire, combines with its alkali. Theſe ſalts cryſtallize, and being much milder than the common fixed alkalis, may be uſed in medicine, and taken internally. They are called *Tachenius*'s *Salts*, becauſe invented by that Chymiſt.

Marine plants yield a fixed alkali analogous to that of ſea-ſalt. As for all other plants or vegetable ſubſtances, the fixed alkalis obtained from them, if rightly prepared and thoroughly calcined, are all perfectly alike, and of the very ſame nature.

The laſt obſervation I have to make on the production of fixed alkalis is, that if the plant you intend to work upon be ſteeped or boiled in water before you burn it, a much ſmaller quantity of ſalt will be obtained from it; nay, it will yield none at all, if repeated boilings have robbed it entirely of thoſe ſaline particles which muſt neceſſarily concur with its earth to form a fixed Alkali.

§. II. *The* ANALYSIS *of* ANIMAL SUBSTANCES.

SUCCULENT animal ſubſtances, ſuch as new-killed fleſh, yield by expreſſion a juice or liquid, which is no other than the phlegm, replete with all the principles of the animal body, except the earth, of which it contains but little. The hard or dry parts, ſuch as the horns, bones, *&c.* yield a ſimilar juice, by boiling them in water. Theſe juices become thick, like a glue or jelly, when their watery parts are evaporated; and in this ſtate they are true extracts of animal matters. Theſe juices afford no cryſtals of eſſential ſalt, like thoſe obtained from vegetables, and ſhew no ſign either of an acid or an alkali.

Great part of the oil which is in the fleſh of animals may be eaſily ſeparated without the help of fire; for it lies in a manner by itſelf: it is commonly in a concrete form, and is called *Fat.* This oil ſomewhat reſembles the fat oils of vegetables; for like them it is mild, unctuous, indiſſoluble in ſpirit of wine, and is ſubtilized and attenuated by the action of fire. But there is not in animals, as in vegetables, any light eſſential oil, which riſes with the heat of boiling water; ſo that properly ſpeaking, animals contain but one ſort of oil.

Few animal ſubſtances yield a perceptible acid. ants and bees are almoſt the only ones from which any can be obtained; and indeed the quantity which they yield is very ſmall, as the acid itſelf is extremely weak.

The reaſon thereof is, that as animals do not draw their nouriſhment immediately from the earth, but feed wholly either on vegetables or on the fleſh of other animals, the mineral acids, which have already undergone a great change by the union contracted between them and the oily matters of the vegetable kingdom, enter into a cloſer union and combination with theſe oily parts while they are paſſing through the organs and ſtrainers of animals; whereby their properties are deſtroyed, or at leaſt ſo impaired that they are no longer ſenſible.

Animal matters yield in diſtillation, firſt, a phlegm, and then, on increaſing the fire, a pretty clear oil, which gradually becomes thicker, blacker, more fetid, and empyreumatic. It is accompanied with a great deal of volatile alkali; and if the fire be raiſed and kept up till nothing more comes over, there will remain in the diſtilling veſſel a coal like that of vegetables; except that when it is reduced to aſhes, no fixed alkali, or at leaſt very little, can be obtained from them, as from the aſhes of vegetables. This ariſes from hence that, as we ſaid before, the ſaline principle in animals being more intimately united with the oil than it is in plants, and being conſequently more attenuated and ſubtilized, is too volatile to enter into the combination of a fixed alkali; on the contrary it is more diſpoſed to join in forming a volatile alkali, which on this occaſion does not riſe till after the oil, and therefore muſt certainly be the production of the fire. It muſt be obſerved, that all we have hitherto ſaid concerning the analyſis of bodies muſt be underſtood of ſuch matters only as have not undergone any ſort of Fermentation.

The chyle and the milk of animals which feed on plants ſtill retain ſome likeneſs to vegetables; becauſe the principles of which theſe liquors are compoſed have not gone through all the changes which they muſt ſuffer before they enter into the animal combination.

Urine and ſweat are excrementitious aqueous liquors, loaded chiefly with the ſaline particles which are of no ſervice towards the nouriſhment of the animal, but paſs through its ſtrainers without receiving any alteration; ſuch as the neutral ſalts which have a fixed alkali for their baſis, and particularly the ſea-ſalt which happens to be in the food of animals, whether it exiſt therein naturally, as it does in ſome plants, or whether the animals eat it to pleaſe their palates.

The ſaliva, the pancreatic juice, and eſpecially the bile, are ſaponaceous liquors, that is, they conſiſt of ſaline and oily particles combined together; ſo that being themſelves diſſolved in an aqueous liquor, they are capable of diſſolving likewiſe the oily parts, and of rendering them miſcible with water.

Laſtly, the blood being the receptacle of all theſe liquors partakes of the nature of each, more or leſs in proportion to the quantity thereof which it contains.

§. III. *The* ANALYSIS *of* MINERAL SUBSTANCES.

MINERALS differ greatly from vegetables, and from animals; they are not near ſo complex as thoſe organized bodies, and their principles are much more ſimple; whence it follows that theſe principles are much more cloſely connected, and that they cannot be ſeparated without the help of fire; which not having on their parts the ſame action and the ſame power as on organized bodies, hath not the ſame ill effect on them; I mean the effect of changing their principles, or even deſtroying them entirely.

I do not here ſpeak of pure, vitrifiable, or refractory earths; of mere metals and ſemi-metals; of pure acids; or even of their ſimpleſt combinations, ſuch as ſulphur, vitriol, alum, ſea-ſalt: of all theſe we have ſaid enough.

We are now to treat of bodies that are more complex, and therefore more ſuſceptible of decompoſition.

Theſe

Theſe bodies are compound maſſes or combinations of thoſe above-mentioned; that is, metallic ſubſtances as they are found in the bowels of the earth, united with ſeveral ſorts of ſand, ſtones, earths, ſemi-metals, ſulphur, &c. When the metallic matter is combined with other matters in ſuch a proportion to the reſt that it may be ſeparated from them with advantage and profit, theſe compounds are called *Ores*: when the caſe is otherwiſe, they are called *Pyrites*, and *Marcaſites*; eſpecially if ſulphur or arſenic be predominant therein, which often happens.

In order to analyſe an ore, and get out of it the metal it contains, the firſt ſtep is to free it from a great deal of earth and ſtones which commonly adhere to it very ſlightly and ſuperficially. This is effected by pounding the ore, and then waſhing it in water; to the bottom of which the metalline parts preſently ſink, as being the heavieſt, while the ſmall particles of earth and ſtone remain ſuſpended ſome time longer.

Thus the metallic part is left combined with ſuch matters only as are moſt intimately complicated with it. Theſe ſubſtances are moſt commonly ſulphur and arſenic. Now as they are much more volatile than other mineral matters, they may be diſſipated in vapours, or the ſulphur may be conſumed, by expoſing the ore which contains them to a proper degree of heat. If the ſulphur and arſenic be deſired by themſelves, the fumes thereof may be catched and collected in proper veſſels and places. This operation is called *Roaſting* an Ore.

The metal thus depurated is now fit to be expoſed to a greater force of fire, capable of melting it. On this occaſion the ſemi-metals and the imperfect metals require the addition of ſome matter abounding in phlogiſton, particularly charcoal-duſt; becauſe theſe metallic ſubſtances loſe their phlogiſton by the action of the fire, or of the fluxes joined with them, and therefore without this precaution would never acquire either the ſplendour or the ductility of a metal. By this means the metallic ſubſtance is more accurately ſeparated from the earthy and ſtony parts, of which ſome portion always remains combined therewith till it is brought to fuſion. For, as we obſerved before, a metallic glaſs or calx only will contract an union with ſuch matters; a metal poſſeſſed of its phlogiſton and metalline form being utterly incapable thereof.

We took notice of the cauſe of this ſeparation above, where we ſhewed that a metal poſſeſſed of its phlogiſton and metalline form will not remain intimately united with any calcined or vitrified matter, not even with its own calx or glaſs.

The metal therefore on this occaſion gathers into a maſs, and lies at the bottom of the veſſel, as being moſt ponderous; while the heterogeneous matters float upon it in the form of a glaſs, or a ſemi-vitrification. Theſe floating matters take the name of *Scoriæ*, and the metalline ſubſtance at bottom is called the *Regulus*.

It frequently happens that the metalline regulus thus precipitated is itſelf a compound of ſeveral metals mixed together, which are afterwards to be ſeparated. We cannot at preſent enter into a detail of the operations neceſſary for that purpoſe: they will appear in our Treatiſe of *Practical Chymiſtry:* but the principles on which they are founded may be deduced from what we have ſaid above concerning the properties of the ſeveral metals and of acids.

It is proper to obſerve, before we quit this ſubject, that the rules here laid down for analyſing ores are not abſolutely general: for example, it is often adviſable to roaſt the ore before you waſh it; for by that means ſome ores are opened, attenuated, and made very friable, which would coſt much trouble and expence, on account of their exceſſive hardneſs, if you ſhould attempt to pound them without a previous torrefaction.

It is alſo frequently neceſſary to ſeparate the ore from part only of its ſtone; ſometimes to leave the whole; and ſometimes to add more to it, before you ſmelt it. This depends on the quality of the ſtone, which always helps to promote fuſion when it is in its own nature fuſible and vitrifiable. It is then called the *Fluor* of the ore: But of this we muſt ſay as we did of the preceding article; it is ſufficient for our preſent purpoſe to lay down the fundamental principles on which the reaſon of every proceſs is built; the deſcription of the operations themſelves being reſerved for our ſecond Part.

We ſhall now give a ſuccinct account of the principal ores and mineral bodies, contenting ourſelves with juſt pointing out the particulars of which they ſeverally conſiſt.

Of the PYRITES.

The yellow Pyrites.

THE yellow Pyrites is a mineral conſiſting of ſulphur, iron, an unmetallic earth, and frequently a little copper: the ſulphur, which is the only one of theſe principles that is volatile, may be ſeparated from the reſt by ſublimation: it uſually makes a fourth, and ſometimes a third, of the whole weight of theſe Pyrites. The other principles are ſeparated from one another by fuſion and reduction with the phlogiſton, which, by metallizing the ferruginous and cupreous earths, parts them from the unmetallic earth: for this earth vitrifies, and cannot afterwards continue united with metallic matters poſſeſſed of their metalline form, as hath been ſaid before.

There is yet another way of decompoſing the yellow Pyrites, which is to let it lye till it effloreſces, or begins to ſhoot into flowers; which is nothing but a ſort of ſlow accenſion of the ſulphur it contains. The ſulphur being by this means decompoſed, its acid unites with the ferruginous and cupreous parts of the Pyrites, and therewith forms green and blue vitriols; which may be extracted by ſteeping in water the Pyrites which has effloreſced or been burnt, and then evaporating the lixivium to a pellicle; for by this means the vitriol will ſhoot into cryſtals.

Sometimes the Pyrites contains alſo an earth of the ſame nature with that of alum: a Pyrites of this ſort, after flowering, yields alum as well as vitriol.

The White Pyrites.

THE white Pyrites contains much arſenic, a ferruginous earth, and an unmetallic earth. The arſenic being a volatile principle may be ſeparated by ſublimation or diſtillation from the reſt, which are fixed: and theſe again may be disjoined from each other by fuſion and reduction, as was ſaid in relation to the yellow Pyrites.

The Copper Pyrites.

THE Copper Pyrites contains ſulphur, copper, and an unmetallic earth. A great deal thereof likewiſe holds arſenic, and its colour approaches more or leſs to orange, yellow, or white, according to the quantity of arſenic in it. It may be decompoſed by the ſame means as the yellow and white Pyrites.

OF ORES.

Of Gold Ores.

GOLD being conſtantly found in its metalline form, and never combined with ſulphur and arſenic, its ores are not, properly ſpeaking, ores; becauſe the metal contained in them is not mineralized. The gold is only lodged between particles of ſtone, earth, or ſand, from which it is eaſily ſeparated by lotion, and by amalgamation with quickſilver. The gold thus found is ſeldom pure, but is frequently alloyed with more or leſs ſilver, from which it is to be ſeparated by quartation.

It is alſo very common to find gold in moſt ores of other metals or ſemi-metals, and even in the Pyrites; but the quantity contained therein is generally ſo ſmall, that it would not pay the coſt of extracting it. However, if any ſhould incline to attempt it, merely out of curioſity, it would be neceſſary to begin with treating theſe ores in the manner proper for ſeparating their metalline part; then to cupel the metalline regulus ſo obtained; and laſtly to refine it by quartation.

Of Silver Ores.

IT is no rare thing to find ſilver, as well as gold, in its metalline form, only lodged in ſundry earths and ſtony matters, from which it may be ſeparated in the ſame manner as gold. But the greateſt quantities of this metal are uſually dug out of the bowels of the earth in a truly mineral ſtate; that is, combined with different ſubſtances, and particularly with ſulphur and arſenic.

Several ſilver ores are diſtinguiſhed by peculiar characteriſticks, and are accordingly denoted by particular names. That which is called the *Vi-*

treous Silver Ore, is ſcarce any thing elſe but a combination of ſilver and ſulphur. Another is known by the name of the *Horny Silver Ore*, becauſe when in thin plates it is ſemi-tranſparent: in this ore the ſilver is mineralized by ſulphur and a little arſenic. The *Red Silver Ore* is of the colour which its name imports, ſometimes more, ſometimes leſs vivid; and is chiefly compoſed of ſilver, arſenic, and ſulphur: it alſo contains a little iron.

Theſe three ores are very rich in ſilver: the firſt contains nearly three fourths of its weight, and the others about two thirds of theirs.

There is a fourth, called the *White Silver Ore*, which though it be heavier, is not ſo rich in ſilver, becauſe it contains much copper. Many other ores contain ſilver, yet are not, properly ſpeaking, ſilver ores; becauſe a much greater quantity of other metals than of ſilver is found in them.

When a ſilver ore is to be decompoſed, in order to have the ſilver pure, or when ſilver is to be extracted out of any ore that contains it, the firſt thing to be done is to roaſt the ore in order to clear it of the volatile minerals: and as ſilver cannot be had pure without the operation of the cupel, which requires more or leſs lead to be joined with it, it is uſual to mix with the torrified ſilver ore a quantity of lead proportioned to that of the heterogeneous matters combined with the ſilver, and to melt the whole together. Part of the added lead vitrifies during the fuſion, and at the ſame time converts ſome of the heterogeneous matters alſo into glaſs, with which it forms a ſcoria that riſes to the ſurface of the matter. The other part of the lead, with which the ſilver is mixed, falls to the bottom in the form of a regulus, which muſt be cupelled in order to have the ſilver pure.

Of Copper Ores.

COPPER is much ſeldomer found in a metalline form, than gold or ſilver: it is commonly in a mineral ſtate: it is mineralized by ſulphur and arſenic: almoſt all its ores contain alſo more or leſs iron; ſometimes a little ſilver or even gold, together with unmetallic earths and ſtones, as all ores do.

Moſt copper ores are of a beautiful green or blue, or elſe in ſhades blended of theſe two colours. The minerals called mountain green, and mountain blue, are true copper ores; not in the form of hard ſtones, like other ores, but crumbly and friable like earth.

Neverthelеſs there are ſeveral copper ores of different colours, as aſh-coloured, whitiſh, and ſhaded with yellow or orange; which colours ariſe from the different proportions of arſenic, ſulphur, and iron, which theſe ores contain.

In order to decompoſe a copper ore, and to extract the copper it contains, it is firſt of all to be freed from as many of its earthy, ſtony, ſulphureous, and arſenical parts, as is poſſible, by roaſting and waſhing; then what remains is to be mixed with a flux compounded of a fixed alkali and ſome inflammable matter; a little ſea-ſalt is to be put over all, and the whole melted by a ſtrong fire. The ſalts facilitate the fuſion and ſcorification of the unmetallic matters, and therewith form a ſlag, which being the lighteſt riſes to the ſurface. The metalline matters are collected below in the form of a ſhining regulus of copper; which, however, is not uſually fine copper, but requires to be purified in the manner to be ſhewn in our ſecond part.

In order to ſeparate the copper from the unmetallic matters, it is abſolutely neceſſary to melt its ore along with inflammable ſubſtances abounding in phlogiſton. For, as this metal is not poſſeſſed of its metalline form while it is in a mineral ſtate, as it is deſtitute of the true quantity of phlogiſton, and, though it were not, would loſe it by the action of the fire, it would come to paſs that if its ore were melted without the addition of any inflammable matter, the cupreous earth or calx would be ſcorified and confounded with the unmetallic matters; and as all metallic matters, except gold and ſilver, are ſubject to this inconvenience as well as copper, the addition of an inflammable ſubſtance, in fluxing all ores that contain them, is a general rule that ought conſtantly to be obſerved.

Of Iron Ores.

IRON is ſeldom found pure and malleable in the earth; yet it is much ſeldomer found in the mineral ſtate, properly ſo called, than any of the other metals: for moſt iron ores are ſcarce any thing more than a ferruginous earth mixed in different proportions with unmetallic earths and ſtones. Some of them, however, contain alſo volatile minerals, ſuch as ſulphur and arſenic; and therefore it is neceſſary to roaſt the iron ores, like all others, before you attempt to extract the metal out of them. That being done, they are to be ſmelted with a flux conſiſting of fuſible and inflammable matters, as the general rule directs.

Iron is the commoneſt of all metals; nay, it is ſo univerſally diffuſed through the earth, that it is difficult to find any ſtone, earth, or ſand, that does not contain ſome of it; and therefore none of theſe are uſually conſidered and treated as iron ores, except ſuch as contain a great deal of that metal, and melt eaſily. The hematites, emery, yellow pyrites, calamine, all contain a pretty conſiderable quantity of iron; but no body attempts to extract it from them, becauſe they are very hard to melt.

Ferruginous earth being naturally of an orange colour, a ſtone or earth may be judged to contain iron, if either naturally or after roaſting it appears to have any ſhade of yellow or red.

The ſingular property which iron has of being attracted by the magnet, and of being the only body, excluſive of all others, that is ſo, likewiſe affords us an eaſy method of diſcovering the preſence of this metal among other matters, where it often exiſts in ſuch a ſmall quantity that it could not otherwiſe be found out. For this purpoſe the body in which iron is ſuſpected to lurk, muſt be pulveriſed and torrefied with ſome inflammable matter; and then the powder thus roaſted being touched with a magnet, or a magnetical bar, if it contains any particles of iron they will infallibly adhere to the magnet or bar.

Of Tin Ores.

TIN is never found in the earth pure and malleable, but always in a mineral ſtate, and always mineralized by arſenic. Tin ores are not ſulphureous; whence it comes that though tin be the lighteſt of all metals, its ores are nevertheleſs heavier than thoſe of other metals, as arſenic greatly exceeds ſulphur in gravity. Some tin ores contain alſo a little iron. The ores of tin are to be waſhed, roaſted, and ſmelted with a reducing flux, according to the general rules.

Of Lead Ores.

LEAD, like tin, is never found but in a mineral ſtate. It is moſt commonly mineralized by ſulphur; yet there are ſome lead ores which alſo contain arſenic.

Lead ores, as well as all others, muſt be roaſted and ſmelted with a reducing flux: however, as it is difficult to free them from all their ſulphur by torrefaction only, the reducing flux employed in their fuſion may be made up with a quantity of iron filings, which being incapable of any union with lead, and having a much greater affinity than that metal with ſulphur, will on this occaſion be of great ſervice by interpoſing between them.

Of Quick-ſilver Ores.

RUNNING Mercury is ſometimes found in certain earths, or grey, friable ſtones; but moſt commonly in a mineral ſtate. It is always mineralized by ſulphur, and by ſulphur alone: ſo that cinabar is the only ore of quick-ſilver that we know of: and a very rich one it is, ſeeing it contains ſix or ſeven times as much mercury as ſulphur.

Roaſting can be of no uſe towards decompoſing the ore of mercury, and ſeparating its ſulphur; becauſe mercury being itſelf very volatile would be carried off by the fire together with the ſulphur. In order therefore to part the two ſubſtances of which cinabar conſiſts, recourſe muſt neceſſarily be had to ſome third body, which will unite with one of them, and by that means ſeparate it from the other. Now all the metals, except gold, having a greater affinity than mercury with ſulphur, ſuch a body is eaſily found: any metal but gold may be employed with ſucceſs in this decompoſition; but as iron hath a greater affinity with ſulphur than any of the reſt, and is moreover the only one that cannot unite with mercury, it muſt on account of theſe two qualities be preferred to all the reſt.

Fixed alkalis are alſo well qualified to abſorb the ſulphur of cinabar. Cinabar muſt be decompoſed in cloſe veſſels, and by the way of diſtillation; otherwiſe the mercury, as ſoon as it ſeparates from the ſulphur, will be diſſipated in vapours and entirely loſt.

IN this operation it is needleſs to add either flux or phlogiſton; becauſe the cinabar is decompoſed without melting, and the mercury, though in a mineral ſtate, contains, like gold and ſilver, all the phlogiſton requiſite to ſecure its metalline properties.

Of the Ores of Regulus of Antimony.

REGULUS of Antimony is always found in a mineral ſtate: it is mineralized by ſulphur; but ſometimes, though rarely, it is alſo combined with a little arſenic.

When the ore of regulus of antimony is to be decompoſed, the firſt thing to be done is to expoſe it to a degree of heat too weak to melt its earthy and ſtony parts, but ſtrong enough to fuſe its reguline together with its ſulphureous parts, which by this means are ſeparated from the earth, and united into one maſs, known by the name of Antimony.

It is plain that this firſt operation, which is founded on the great fuſibility of antimony, produces, with regard to the ore of regulus of antimony, the ſame effect that waſhing hath on other ores: ſo that after this firſt fuſion nothing more is requiſite to the obtaining of a pure regulus of antimony, but to ſeparate it from its ſulphur by roaſting, and to melt it with ſome matter abounding in phlogiſton, in the ſame manner as other metallic matters are treated. The term calcination is generally uſed to expreſs this torrefaction of antimony, by means whereof the metallic earth of the regulus of antimony is ſeparated from its ſulphur.

As regulus of antimony hath, like mercury. much leſs affinity with ſulphur than the other metals have, it follows that antimony may be decompoſed by the ſame means as cinabar; but the regulus ſo obtained is adulterated with a portion of the additament made uſe of, which combines therewith.

There is ſtill another proceſs employed for obtaining the regulus of antimony: it conſiſts, as was mentioned in its place, in detonating the mineral with a mixture of nitre and tartar, applied in ſuch a proportion that, after the detonation has conſumed the ſulphur, there may remain ſo much inflammable matter as will be ſufficient to furniſh the metalline earth of the antimony with the phlogiſton neceſſary to preſerve its metallic properties. But by this method leſs regulus is produced, than by calcining, or torrefying, and reducing as uſual.

Of the Ores of Biſmuth.

THE ore of Biſmuth conſiſts of the ſemi-metal mineralized by the arſenic, and of an unmetallic earth. It is very eaſy to decompoſe this ore, and to extract the biſmuth it contains: for this purpoſe it need only be expoſed to a moderate heat, whereby the arſenic will be diſſipated in vapours, and the biſmuth melted, which will then ſeparate from the unmetallic earth. This earth, at leaſt in ſeveral ores of biſmuth, poſſeſſes the property of tinging all vitrifiable matters with which it is melted of a beautiful blue colour.

To decompoſe the ore of biſmuth no flux or inflammable matter is uſed; becauſe this ſemi-metal is poſſeſſed, even in its mineral ſtate, of all the phlogiſton requiſite to maintain its metalline properties; and its great fuſibility makes it unneceſſary to melt the metallic earth contained in its ore.

Of the Ores of Zinc.

ZINC is not generally obtained from a particular ore of its own; but ſublimes during the fuſion of a mineral, or rather a confuſed maſs of minerals, that contains this ſemi-metal together with iron, copper, lead, ſulphur, arſenic, and, like all other ores, an unmetallic earth.

Nevertheleſs there is a ſubſtance which may be conſidered as the proper ore of zink, becauſe it contains a pretty large quantity of that ſemi-metal, a little iron, and an unmetallic earth. It is called Calamine, or *Lapis Calaminaris*: but hitherto the art of procuring zinc directly from this mineral hath no where been practiſed. Calamine is commonly employed only to convert copper into braſs or a yellow metal, by cementing it therewith. Indeed till lately no eaſy or practicable method of obtaining pure zinc from calamine was publickly known; for that ſemi-metal being volatile and very inflammable, its ore cannot be fuſed like others. Mr. Margraaf was the firſt who, by mixing powdered charcoal with calamine in cloſe veſſels, obtained a perfect zinc from it, by the means of diſtillation or ſublimation, as ſhall be ſhewn in our Practical Chymiſtry.

Of Arſenical Minerals.

Arsenic, as well as ſulphur, is naturally combined with almoſt all ores, or minerals containing metallic ſubſtances. As it is very volatile, while the matters with which it is united are fixed, at leaſt in compariſon therewith, it is eaſily ſeparated by ſublimation.

The minerals that contain moſt arſenic are the white pyrites, orpiment, and cobalt. We have already conſidered the white pyrites: as to Orpiment, it conſiſts of ſulphur and arſenic. Both theſe ſubſtances being very volatile, it is difficult to ſeparate them by ſublimation: yet, with proper management, and a due regulation of the fire, this ſeparation may be effected; becauſe ſulphur ſublimes a little more eaſily than arſenic. But it is more convenient, as well as more expeditious, to make uſe of ſome additament that hath a greater affinity with one of thoſe ſubſtances than with the other. Fixed alkalis and mercury, both of which have more affinity with ſulphur than with arſenic, may be very properly employed on this occaſion.

Cobalt is a mineral compoſed of arſenic, an unmetallic earth, and frequently biſmuth: and as none of theſe are very volatile, except the arſenic, this may be eaſily ſeparated from the reſt by ſublimation. The unmetallic earth which remains has, like that of the ore of biſmuth, the property of giving a blue colour to any vitrifiable matters melted with it; whence it is conjectured that cobalt and the ore of biſmuth have a great reſemblance, or are often blended with each other. Nevertheleſs Mr. Brant, an ingenious Swediſh Chymiſt, inſiſts that they are very different: he pretends that the metallic ſubſtance contained in the true cobalt is a ſemi-metal of a peculiar nature, which hath been erroneouſly confounded with biſmuth: and indeed he proves by a great number of curious experiments, related in the Memoirs of the Academy of Upſal, that theſe two metallic ſubſtances have properties that are eſſentially different: to that which is obtained from cobalt he gives the name of Regulus of Cobalt.

Beſides the minerals already recited, there is found in the bowels of the earth another ſpecies of compound body, of which we have already taken notice; but which is ſuppoſed, with ſome degree of probability, to belong as much to the vegetable as to the mineral kingdom: I mean the Bitumens; which the beſt obſervations oblige us to conſider as vegetable oils, that by lying long in the earth have contracted an union with the mineral acids, and by that means acquired the thickneſs, conſiſtence, and other properties obſervable in them.

By diſtillation they yield an oil, and an acid not unlike a mineral acid. Mr. Bourdelin has even demonſtrated, by a very artful and ingenious proceſs, that amber contains a manifeſt acid of ſea-ſalt. See the Memoirs of the Royal Academy of Sciences.

CHAP. XVII.

Explanation of the Table of Affinities.

IT hath been ſhewn in the courſe of this work that the cauſes of almoſt all the phenomena, which Chymiſtry exhibits, are deducible from the mutual affinities of different ſubſtances, eſpecially the ſimpleſt. We have already explained, (ſee Chap. II.) what is meant by Affinities, and have laid down the principal laws to which the relations of different bodies are ſubject. The late Mr. Geoffroy, one of the beſt Chymiſts we have had, being convinced of the advantages which all who cultivate Chymiſtry would receive from having conſtantly before their eyes a ſtate of the beſt aſcertained relations between the chief agents in Chymiſtry, was the firſt who undertook to reduce them into order, and unite them all in one point of view, by means of a table. We are of opinion, with that great man, that this Table will be of conſiderable uſe to ſuch as are beginning to ſtudy Chymiſtry, in helping them to form a juſt idea of the relations which different ſubſtances have with one another; and that the practical Chymiſt will thereby be enabled to account for what paſſes in ſeveral of his operations otherwiſe difficult to be underſtood, as well as to judge what may be expected to reſult from mixtures of different compounds. Theſe reaſons have induced us to inſert it at the end of this elementary treatiſe, and to give a ſhort explanation of it here; eſpecially as it will ſerve, at the ſame time, for a recapitulation of the whole work, in which the ſeveral axioms of this Table are diſperſed.

You have it here juſt as it was drawn up by Mr. Geoffroy, without any addition or alteration. I own, however, that it might be improved both ways; for ſince the death of that great Chymiſt many experiments have been made, ſome of which have diſcovered new affinities, and others have raiſed exceptions to ſome of thoſe laid down by him. But ſeveral reaſons diſſuade me from publiſhing a new Table of Affinities, containing all the emendations and innovations that might be made in the old one.

The firſt is, that many of the affinities lately diſcovered are not yet ſufficiently verified, but, on the contrary, ſubject to be conteſted: in ſhort, they are perhaps liable to more conſiderable objections and exceptions than the other.

The ſecond is, that as Mr. Geoffroy's Table contains all the fundamental affinities, it is more ſuitable to an Elementary Treatiſe than a much fuller one would be; ſeeing this would neceſſarily ſuppoſe the knowledge of many things not treated of by us, and of which it was not proper to ſay any thing in ſuch a book.

However, as it is eſſential to our purpoſe that we lead none into error, we ſhall take care, in explaining the affinities delivered by Geoffroy, to mention the principal objections and exceptions to which they are liable: we ſhall moreover add a very few new ones, confining ourſelves to ſuch only as are elementary and well aſcertained.

The upper line of Mr. Geoffroy's Table comprehends ſeveral ſubſtances uſed in Chymiſtry. Under each of thoſe ſubſtances are ranged in diſtinct columns ſeveral matters compared with them, in the order of their relation to that firſt ſubſtance; ſo as that which is the neareſt to it is that which hath the greateſt affinity with it, or that which none of the ſubſtances ſtanding below it can ſeparate therefrom; but which, on the contrary, ſeparates them all when they are combined with it, and expels them in order to join itſelf therewith. The ſame is to be underſtood of that which occupies the ſecond place of affinity; that is, it has the ſame property with regard to all below it, yielding only to that which is above it: and ſo of all the reſt.

At the top of the firſt column ſtands the character which denotes an Acid in general. Immediately under this ſtands the mark of a Fixed Alkali, being placed there as the ſubſtance which has the greateſt affinity with an Acid. After the Fixed Alkali appears the Volatile Alkali, whoſe affinity with Acids yields only to the Fixed Alkali. Next come the Abſorbent Earths; and laſt of all Metallic Subſtances. Hence it follows that when a Fixed Alkali is united with an Acid it cannot be ſeparated therefrom by any other ſubſtance; that a Volatile Alkali united with an Acid cannot be ſeparated from it by any thing but a Fixed Alkali, that an Abſorbent Earth combined with an Acid may be ſeparated from it either by a Fixed or by a Volatile Alkali; and laſtly, that any Metallic Subſtance combined with an Acid may be ſeparated from it by a Fixed Alkali, a Volatile Alkali, or an Abſorbent Earth.

There are many important remarks to be made on this firſt column. Firſt, it is making the rule too general to ſay that any Acid whatever has a greater affinity with a Fixed Alkali, than with any other ſubſtance: and indeed Mr. Geoffroy himſelf hath made an exception with reſpect to the Vitriolic Acid; for in the fourth column, at the head of which ſtands that Acid, we find the ſign of the

Phlogiſton placed above that of the Fixed Alkali, as having a greater affinity than the Fixed Alkali with the Vitriolic Acid. This is founded on the famous experiment, wherein Vitriolated Tartar and Glauber's Salt are decompounded by means of the Phlogiſton, which ſeparates the Fixed Alkalis of theſe Neutral Salts, and uniting with the Vitriolic Acid contained in them forms therewith a Sulphur.

Secondly, Nitre deflagrates, and is decompoſed, by the contact of any inflammable matter whatever that is actually on fire; and the operation which produces Phoſphorus is no other than a decompoſition of ſea-ſalt, whoſe Acid quits its Alkaline baſis to join with the Phlogiſton: now theſe facts furniſh very ſtrong reaſons for believing that both theſe Acids, as well as the Vitriolic, have a ſtronger affinity with the Phlogiſton than with a Fixed Alkali. Laſtly, as ſeveral experiments ſhew the Vegetable Acids to be only the Mineral Acids diſguiſed and mortified, there are ſufficient grounds for ſuſpecting that Acids in general have a greater affinity with the Phlogiſton than with Fixed Alkalis: ſo that inſtead of making an exception with regard to the Vitriolic Acid, it would perhaps be better to lay down this greater affinity as common to all Acids whatever, and to place the Phlogiſton in the firſt column, immediately under the character which denotes an Acid in general. This theory, however, ſtands in need of confirmation from other experiments *.

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* Mr. Margraaf, an able German Chymiſt, has made ſeveral experiments which induce him to think that the Acid of Phoſphorus is of a particular kind, and different from that of ſea-ſalt. May it not be the Marine Acid, but altered by the union it has contracted with the phlogiſton? Or may it not be, with reſpect to Phoſphorus, what the volatile ſulphureous ſpirit is, with reſpect to Sulphur? See the Memoirs of the Royal Academy of Sciences of Berlin.

Thirdly, in this ſame column the character of a Volatile Alkali is ſet above that of an Abſorbent Earth, as having a greater affinity with Acids; and yet theſe Abſorbent Earths decompoſe the Ammoniacal ſalts, drive away the Volatile Alkali from the Acids, and aſſume its place. This is one of the firſt objections made againſt Mr. Geoffroy's Table. His anſwer thereto is printed in the Memoirs of the Academy of Sciences for 1718, where his Table alſo is to be found. We have already declared our opinion about this matter in treating of a Volatile Alkali.

Fourthly, in 1744, Mr. Geoffroy, brother to the author of the Table, who hath done no leſs honour to Chymiſtry than that eminent phyſician, gave in a Memoir containing an exception to the laſt affinity in the firſt column; namely, that which places Abſorbent Earths above Metallic Subſtances. He therein ſhews that Alum may be converted into Copperas by boiling it in Iron veſſels; that on this occaſion the Iron precipitates the Earth of the Alum, ſeparates it from its Acid, and aſſumes its place; ſo that of courſe it muſt have a greater affinity, than the Abſorbent Earth of Alum, with the Vitriolic Acid.

At the head of the ſecond column ſtands the character of the Marine Acid, which ſignifies that the affinities of this Acid are the ſubject of the column. Immediately below it is placed the mark of Tin. As this is a Metalline ſubſtance, and as the firſt column places Metalline ſubſtances in the loweſt degree of affinity with all Acids, it is plain we muſt ſuppoſe Fixed Alkalis, Volatile Alkalis, and Abſorbent Earths, to be placed here in order after the Marine Acids, and before Tin. Tin, then, is of all Metalline ſubſtances that which has the greateſt affinity with the Marine Acid; and then follow Regulus of Antimony, Copper, Silver, Mercury. Gold comes laſt of all; and there are no leſs than two vacant places above it. By this means it is in ſome ſort excluded from the rank of ſubſtances that have an affinity with the Marine Acid. The reaſon thereof is that this Acid alone is not capable of diſſolving Gold and combining therewith, neceſſarily requiring for that purpoſe the aid of the Nitrous Acid, or at leaſt of the Phlogiſton.

The third column exhibits the affinities of the Nitrous Acid, the character whereof ſtands at its head. Immediately below it is the ſign of Iron, as the metal which has the greateſt affinity with this Acid; and then follow other metals, each according to the degree of its relation; to wit, Copper, Lead, Mercury, and Silver. In this column, as in the preceding one, we muſt ſuppoſe the ſubſtances, which in the firſt column ſtand above Metallic ſubſtances, to be placed in their proper order before Iron.

The fourth column is intended to repreſent the affinities of the Vitriolic Acid. Here Mr. Geoffroy has placed the Phlogiſton as the ſubſtance which has the greateſt affinity with this Acid, for the reaſon given in our explanation of the firſt column. Below it he has ranked Fixed Alkalis, Volatile Alkalis, and Abſorbent Earths, to ſhew that this is an exception to the firſt column. As to Metalline ſubſtances, he has ſet down but three, being thoſe with which the Vitriolic Acid has the moſt perceptible affinity: theſe metals, placed in the order of their affinities, are Iron, Copper, and Silver.

The fifth column ſhews the affinities of Abſorbent Earths. As theſe Earths have no ſenſible affinity but with Acids, this column contains only the characters of the Acids ranked according to the degree of their ſtrength, or affinity with the Earths; to wit, the Vitriolic, the Nitrous, and the Marine

Acids. Underneath this laſt might be placed the Acid of Vinegar, or the Vegetable Acid.

The ſixth column expreſſes the affinities of Fixed Alkalis with Acids, which are the ſame with thoſe of Abſorbent Earths. Moreover, we find Sulphur placed here below all the Acids; becauſe Liver of Sulphur, which is a combination of Sulphur with a Fixed Alkali, is actually decompounded by any Acid: for any Acid precipitates the Sulphur and unites with the Alkali.

Immediately over the Sulphur, or in the ſame ſquare with it, might be ſet a mark denoting the Volatile Sulphureous Spirit; becauſe, like Sulphur, it has leſs affinity than any other Acid with Fixed Alkalis. Oils might alſo be ranked with Sulphur, becauſe they unite with Fixed Alkalis, and therewith form Soaps which are decompounded by any Acid whatever.

The ſeventh column points out the affinities of Volatile Alkalis, which are likewiſe the ſame as thoſe of Abſorbent Earths; and the Vegetable Acid might be placed here alſo under the Marine Acid.

The eighth column ſpecifies the affinities of Metallic ſubſtances with Acids. The affinities of the Acids, which with reſpect to Fixed Alkalis, Volatile Alkalis, and Abſorbent Earths, ſucceeded each other uniformly, do not appear in the ſame order here. The Marine Acid, inſtead of being placed below the Vitriolic and Nitrous Acids, ſtands, on the contrary, at their head; becauſe, in fact, this Acid ſeparates Metalline ſubſtances from all the other Acids with which they happen to be united, and forcing theſe Acids to quit poſſeſſion intrudes into their place. Nevertheleſs, this is not a general rule; for ſeveral Metalline ſubſtances muſt be excepted, particularly Iron and Copper.

The ninth column declares the affinities of Sulphur. Fixed Alkalis, Iron, Copper, Lead, Silver, Regulus of Antimony, Mercury, and Gold, ſtand below it in the order of their affinities. With regard to Gold it muſt be obſerved, that it will not unite with pure Sulphur; it ſuffers itſelf to be diſſolved only by the Liver of Sulphur, which is known to be a compoſition of Sulphur and Fixed Alkali.

At the head of the tenth column appears Mercury, and beneath it ſeveral Metalline ſubſtances, in the order of their affinities with it. Thoſe Metalline ſubſtances are Gold, Silver, Lead, Copper, *Zinc*, and Regulus of Antimony.

It is proper to remark on this column that Regulus of Antimony, which ſtands the loweſt, unites but very imperfectly with Mercury; and that after a ſeeming union of theſe two Metallic ſubſtances hath been obtained, by a tedious triture with the addition of water, they do not continue long united, but ſpontaneouſly ſeparate from each other in a ſhort time. Iron and Tin are here excluded; the former with great reaſon, becauſe hitherto it hath not been clearly proved, by any known experiment, that ever Mercury was united with Iron: but the ſame objection cannot be made to Tin, which amalgamates very well with Mercury, and might therefore be placed in this column nearly between Lead and Copper. I uſe the word *nearly*, becauſe the different degrees of affinity between Metalline ſubſtances and Mercury are not ſo exactly determined, as the other relations before conſidered; ſeeing they generally unite with it, without excluding one another. We can therefore ſcarce judge of the degree of affinity that belongs to each, but by the greater or leſs readineſs of each to amalgamate therewith.

The eleventh column ſhews that Lead has a greater affinity with Silver than with Copper.

The twelfth, that Copper has a greater affinity with Mercury than with Calamine.

The thirteenth, that Silver has a greater affinity with Lead than with Copper.

The fourteenth contains the affinities of Iron. Regulus of Antimony ſtands immediately underneath it, as being the Metallic ſubſtance which has the greateſt affinity with it. Silver, Copper, and Lead are placed together in the next ſquare below, becauſe the degrees of affinity which thoſe Metals have with Iron are not exactly determined.

The ſame is to be ſaid of the fifteenth column: Regulus of Antimony ſtands at its head; Iron is immmediately below it; and below the Iron the ſame three Metals occupy one ſquare as before.

Laſtly, the ſixteenth column indicates that Water has a greater affinity with Spirit of Wine than with Salts. By this general expreſſion muſt not be underſtood any Saline ſubſtance whatever; but only the Neutral Salts, which Spirit of Wine frees from the water that kept them in ſolution. Fixed Alkalis, on the contrary, as well as the Mineral Acids, have a greater affinity than Spirit of Wine with Water: ſo that theſe Saline ſubſtances, being well dephlegmated and mixed with Spirit of Wine, imbibe the water it contains, and rectify it.

To theſe might be added another ſhort column, having Spirit of Wine at its head; immediately below it ſhould be the character of Water, and below that the mark of Oil. This column would ſhew that Spirit of Wine has a greater affinity with Water than with Oils; becauſe any Oily matter whatever, that is diſſolved in Spirit of Wine, may be actually ſeparated from it by the affuſion of Water. This rule admits of no exception but in one caſe, which is when the oily ſubſtance partakes of the nature of ſoap, by having contracted an union with ſome ſaline matter. But as this muſt be imputed wholly to that adventitious ſaline matter being ſuperadded to the oily ſubſtance, it is no juſt foundation for an exception, and the affinity in queſtion is nevertheleſs general.

We have now delivered every thing material that we had to ſay concerning Mr. Geoffroy's Table of Affinities. It is, as we obſerved before, of exceeding great ſervice, as it collects into one view the principal truths laid down in this Treatiſe. Indeed the moſt advantageous way of uſing it is, not to delay conſulting it till you have read the book through, but to turn to it while you are reading, as oft as any affinity between bodies is treated of; which it will imprint more ſtrongly on your mind, by repreſenting it in a manner before your eyes.

CHAP. XVIII.

The THEORY *of* CONSTRUCTING *the* VESSELS *moſt commonly uſed in* CHYMISTRY.

CHYMISTS cannot perform the operations of their art without the help of a conſiderable number of veſſels, inſtruments, and furnaces, adapted to contain the bodies on which they intend to work, and to apply to them the ſeveral degrees of heat required by different proceſſes. It is therefore proper, before we advance to the operations themſelves, to conſider particularly and minutely what relates to the inſtruments with which they are to be performed.

Veſſels intended for Chymical Operations ſhould, to be perfect, be able to bear, without breaking, the ſudden application of great heat and great cold; be impenetrable to every thing, and unalterable by any ſolvent; unvitrifiable, and capable of enduring the moſt violent fire without melting: but hitherto no veſſels have been found with all theſe qualities united.

They are made of ſundry materials, namely, of metal, of glaſs, and of earth. Metalline veſſels, eſpecially thoſe made of Iron or Copper, are apt to be corroded by almoſt every ſaline, oily, or even aqueous ſubſtance. For this reaſon, in order to render the uſe of them a little more extenſive, they are tinned on the inſide. But, notwithſtanding this precaution they are on many occaſions not to be truſted; and ſhould never be employed in any nice operations which require great accuracy: they are, moreover, incapable of reſiſting the force of fire.

Earthen veſſels are of ſeveral ſorts. Some, that are made of a refractory earth, are capable of being ſuddenly expoſed to a ſtrong fire without breaking, and even of ſuſtaining a great degree of heat for a conſiderable time: but they generally ſuffer the vapours of the matters which they contain, as well as vitrified metals, to paſs through them; eſpecially the glaſs of lead, which eaſily penetrates them, and runs through their pores as through a ſieve. There are others made of an earth that when well baked looks as if it were half vitrified: Theſe being much leſs porous are capable of retaining the vapours of the matters which they contain, and even glaſs of lead in fuſion; which is one of the ſevereſt trials a veſſel can be put to: but then they are more brittle than the other ſort,

Good glaſs veſſels ſhould conſtantly be employed in preference to all others, whenever they can poſſibly be uſed: and that not only becauſe they are no way injured by the moſt active ſolvents, nor ſuffer any part of what they contain to paſs through, but alſo becauſe their tranſparency allows the Chymiſt to obſerve what paſſes within them; which is always both curious and uſeful. But it is pity that veſſels of this ſort ſhould not be able to endure a fierce fire without melting. We ſhall take care, when we come to deſcribe the ſeveral ſorts of chymical inſtruments, and the manner of uſing them, to note what veſſels are to be preferred to others on different occaſions.

Diſtillation, as hath been already ſaid, is an operation by which we ſeparate from a body, by the help of a gradual heat, the ſeveral principles of which it conſiſts.

There are three methods of diſtilling. The firſt is performed by applying the heat over the body whoſe principles are to be extracted. In this caſe, as the liquors when heated and converted into vapours conſtantly endeavour to fly from the center of heat, they are forced to re-unite in the lower part of the veſſel that contains the matter in diſtillation, and ſo paſſing through the pores or holes of that veſſel, they fall into another cold veſſel applied underneath to receive them. This way of diſtilling is on this account called Diſtilling *per deſcenſum*. It requires no other apparatus than two veſſels figured like ſegments of hollow ſpheres, whereof that which is pierced with little holes, and intended to contain the matter to be diſtilled, ought to be much leſs than the other which is to contain the fire, and cloſe its aperture exactly; the whole together being ſupported vertically upon a third veſſel, which is to ſerve the purpoſe of a recipient, admitting into its mouth the convex bottom of the veſſel containing the matter to be diſtilled, which muſt accurately fill it. This method of diſtilling is but little uſed.

The ſecond method of diſtilling is performed by applying the heat underneath the matter to be decompoſed. On this occaſion the liquors being heated, rarefied, and converted into vapours, riſe, and are condenſed in a veſſel contrived for that purpoſe, which we ſhall preſently deſcribe. This way of diſtilling is called Diſtilling *per aſcenſum*, and is much uſed.

The veſſel in which this diſtillation *per aſcenſum* is performed we call an Alembic.

There are ſeveral ſorts thereof differing from one another both in the matter of which and the manner in which they are made.

Thoſe employed to draw the odoriferous waters and eſſential oils of plants are generally made of copper, and conſiſt of ſeveral pieces. The firſt, which is deſigned to contain the plant, is formed nearly like a hollow cone, the vertex whereof is drawn out in the ſhape of a hollow cylinder or tube: this part is named the Cucurbit, and its tube the Neck of the alembic. To the upper end of this tube another veſſel is ſoldered: this is called the Head, and commonly has likewiſe the form of a cone, joined to the neck of the alembic by its baſe, round which on the inſide is hollowed a ſmall groove communicating with an orifice that opens at its moſt depending part. To this orifice is ſoldered a ſmall pipe in a direction ſloping downwards, which is called the Noſe, Spout or Break of the alembic.

As ſoon as the matters contained in the alembic grow hot, vapours begin to ariſe from them, and aſcending through the neck of the alembic into the head, are by the ſides thereof ſtopped and condenſed: from thence they trickle down in little ſtreams to the groove, which conveys them to the ſpout; and by that they paſs out of the alembic into a glaſs veſſel with a long neck, the end of the ſpout being introduced into that neck and luted thereto.

To facilitate the refrigeration and condenſation of the vapours circulating in the head, all alembics of metal are moreover provided with another piece, which is a kind of large pan of the ſame metal, fitted and ſoldered round the head. This piece ſerves to keep cold water in, which inceſſantly cools the head, and therefore it is called the Refrigeratory. The water in the refrigeratory itſelf grows hot after ſome time, and muſt therefore be changed occaſionally ; the heated water being firſt drawn off by means of a cock fixed near the bottom of the refrigeratory. All copper alembics ſhould be tinned on the inſide for the reaſons already given.

When ſaline ſpirits are to be diſtilled, alembics of metal muſt not be uſed ; becauſe the ſaline vapours would corrode them. In this caſe recourſe muſt be had to alembics of glaſs. Theſe conſiſt of two pieces only ; namely, a cucurbit, whoſe ſuperiour orifice is admitted into and exactly luted with its head, which is the ſecond piece.

In general, as alembics require that the vapours of the matter to be diſtilled ſhould riſe to a conſiderable heighth, they ought to be uſed only when the moſt volatile principles are to be drawn from bodies: And the lighter and more volatile the ſubſtances to be ſeparated by diſtillation are, the taller muſt the alembic be ; becauſe the moſt ponderous parts, being unable to riſe above a certain heighth, fall back again into the cucurbit as ſoon as they arrive there, leaving the lighter to mount alone, whoſe volatility qualifies them to aſcend into the head.

When a matter is to be diſtilled that requires a very tall alembic, and yet does not admit of a metalline veſſel, the end will be beſt anſwered by a glaſs veſſel of a round or oval ſhape, having a very long neck, with a ſmall head fitted to its extremity. Such a veſſel ſerves many purpoſes : It is ſometimes employed as a receiver, and at other times as a digeſting veſſel ; on which laſt occaſion it goes under the name of a Matraſs.

When one of theſe provided with a head is applied to the purpoſe of diſtilling, it forms a ſort of alembic.

There are ſome alembics of glaſs, blown in ſuch a manner by the workmen, that the body and head form but one continued piece. As theſe alembics do not ſtand in need of having their ſeveral pieces luted together, they are very uſeful on ſome occaſions, when ſuch exceeding ſubtile vapours riſe as are capable of tranſpiring through lutes. The head muſt be open at the top, and provided with a ſhort tube, through which by means of a funnel with a long pipe, the matter to be diſtilled may be introduced into the cucurbit. This is to be exactly cloſed with a glaſs ſtopple, the ſurface whereof muſt be made to fit the inſide of the tube in every point, by rubbing thoſe two pieces well together with emery.

Another ſort of alembic hath alſo been invented, which may be uſed with advantage when cohobation is required; that is, when the liquor obtained by diſtillation is to be returned upon the matter in the cucurbit; and eſpecially when it is intended that this cohobation ſhall be repeated a great number of times. The veſſel we are ſpeaking of is conſtructed exactly in the ſame manner as that laſt deſcribed; except that its beak, inſtead of being in a ſtraight line as in the other alembics, forms a circular arch, and re-enters the cavity of the cucurbit, in order to convey back again the liquor collected in the head. This inſtrument hath commonly two beaks oppoſite to each other, both turned in this manner, and is called a Pelican: It ſaves the artiſt the trouble of frequently unluting and reluting his veſſels, as well as the loſs of a great many vapours.

There are certain ſubſtances which in diſtillation afford matters in a concrete form, or riſe wholly in the form of a very light powder, called Flowers.

When ſuch ſubſtances are to be diſtilled, the cucurbit which contains them is covered with a head without a noſe, which is named a Blind-head.

When the flowers riſe in great quantities and very high, a number of heads is employed to collect them; or rather a number of a kind of pots, conſiſting of a body only without any bottom, which fitting one into the other form a canal, that may be lengthened or ſhortened at pleaſure, according as the flowers to be ſublimed are more or leſs volatile. The laſt of the heads, which terminates the canal, is quite cloſe at one end, and makes a true blind-head. Theſe veſſels are called Aludels: they are uſually of earthen or ſtone-ware.

All the veſſels above mentioned are fit only for diſtilling ſuch light volatile matters as can be eaſily raiſed and brought over; ſuch as phlegm, eſſential oils, fragrant waters, acid oily ſpirits, volatile alkalis, *&c.* But when the point is to procure by diſtillation principles that are much leſs volatile, and incapable of riſing high, ſuch as the thick fetid oils, the vitriolic, the nitrous, and the marine acids, *&c.* we are are under a neceſſity of having recourſe to other veſſels, and another manner of diſtilling.

It is eaſy to imagine that ſuch a veſſel muſt be much lower than the alembic. It is indeed no more than a hollow globe, whoſe upper part degenerates into a neck or tube, that is bent into a horizontal poſition; for which reaſon this inſtrument is called a Retort: it is always of one ſingle piece.

The matter to be diſtilled is introduced into the body of the retort by means of a ladle with a long tubular ſhank. Then it is ſet in a furnace built purpoſely for this uſe, and ſo that the neck of the retort coming out of the furnace may, like the noſe of the alembic, ſtand in a ſloping poſition, to facilitate the egreſs of the liquors, which by its means are conveyed to a receiver, into which it is introduced, and with which it is luted. This way of diſtilling, in which the vapours ſeem rather to be driven out of the veſſel horizontally and laterally, than raiſed up and ſublimed, is for that reaſon called Diſtillation *per latus*.

Retorts are, of all the inſtruments of diſtillation, thoſe that muſt ſuſtain the greateſt heat, and reſiſt the ſtrongeſt ſolvents; and therefore they muſt not be made of metal. Some however, which are made of iron may do well enough on certain occaſions: the reſt are either of glaſs or earth. Thoſe of glaſs, for the reaſons above given, are preferable to the other ſort, in all caſes where they are not to be expoſed to ſuch a force of fire as may melt them. The beſt glaſs, that which ſtands both heat and ſolvents beſt, is that in which there are feweſt alkaline ſalts: of this ſort is the green German glaſs: the beautiful white cryſtal glaſs is far from being equally ſerviceable.

Retorts, as well as alembics, may be of different forms. For example, ſome matters are apt to ſwell and riſe over the neck of the retort in ſubſtance, without ſuffering any decompoſition; when ſuch matters are to be diſtilled in a retort, it is proper that the body of the veſſel, inſtead of being globular, be drawn out into the form of a pear, ſo as nearly to reſemble that of a cucurbit. In a retort of this kind, the diſtance between the bottom and the neck being much greater than in thoſe whoſe bodies are ſpherical, the matters contained have much more room for expanſion; ſo that the inconvenience here mentioned is thereby prevented. Retorts of this form are called Engliſh retorts: as they hold the middle place between alembics and common retorts, they may be uſed to diſtill ſuch matters as have a mean degree of voaltility between the greateſt and the leaſt.

It is moreover proper to have in a laboratory ſundry retorts with necks of different diameters. Wide necks will be found the fitteſt for conveying thick matters, and ſuch as readily become fixed; for inſtance, ſome very thick fetid oils, butter of antimony, *&c.* for as theſe matters acquire a conſiſtence as ſoon as they are out of the reach of a certain degree of heat, they would ſoon choak up a narrow neck, and by ſtopping the vapours, which riſe at the ſame time from the retort, might occaſion the burſting of the veſſels.

Some retorts are alſo made with an opening on their upper ſide, like that of tubulated glaſs alembics, which is to be cloſed in the ſame manner with a glaſs ſtopple. Theſe retorts are alſo called tubulated retorts and ought always to be uſed whenever it is neceſſary to introduce freſh matter into the retort during the operation; ſeeing it may be done by means of this invention, without unluting and reluting the veſſels; which ought always to be avoided as much as poſſible.

One of the things that moſt perplexes the Chymiſts, is the prodigious elaſticity of many different vapours, which are frequently diſcharged with impetuoſity during the diſtillation, and are even capable of burſting the veſſels with exploſion, and with danger to the artiſt. On ſuch occaſions it is abſolutely neceſſary to give theſe vapours vent, as we ſhall direct in its proper place: but as that can never be done without loſing a great many of them; as ſome of them in particular are ſo elaſtic that ſcarce any at all would remain in the veſſel; for inſtance, thoſe of the ſpirit of nitre, and eſpecially thoſe of the ſmoking ſpirit of ſalt; the practice is to make uſe of very large receivers, of about eighteen or twenty inches diameter, that the vapours may have ſufficient room to circulate in, and by applying to the wide ſurface preſented them by the extenſive inſide of ſuch a large veſſel, may be condenſed into drops. Theſe huge receivers are commonly in the form of hollow globes, and are called Ballons.

To give theſe vapours ſtill more room, ballons have been contrived with two open gullets in each, diametrically oppoſite to one another; whereof one admits the neck of the retort, and the other is received by one of the gullets of a ſecond ballon of the ſame form, which is joined in like manner to a third, and ſo on. By this artifice the ſpace may be enlarged at pleaſure. Theſe ballons with two necks are called Adopters.

Operations on bodies that are abſolutely fixed, as metals, ſtones, ſand, *&c.* require only ſuch veſſels as are capable of containing thoſe bodies and reſiſting the force of fire. Theſe veſſels are little hollow pots, of different dimenſions, which are called Crucibles. Crucibles can hardly be made of any thing but earth; they ought to have a cover of the ſame material fitted to ſhut them cloſe. The beſt earth we know is that whereof thoſe pots are made in which butter is brought from Bretagne: theſe pots themſelves are exceeding good crucibles; and they are almoſt the only ones that are capable of holding glaſs of lead in fuſion, without being penetrated by it.

For the roaſting of ores, that is, freeing them by the help of fire from their ſulphureous and arſenical parts, little cups made of the ſame material with crucibles are uſed; but they are made flat, ſhallow, and wider above than below, that theſe volatile matters may the more freely exhale. Theſe veſſels are called Teſts, or Scorifiers: they are ſcarce ever uſed but in the Docimaſtic art, that is, in making ſmall Aſſays of ores.

CHAP. XIX.

The THEORY *of* CONSTRUCTING *the* FURNACES *moſt commonly uſed in* CHYMISTRY.

SKILL in conducting and applying fire properly, and determining its different degrees, is of very great conſequence to the ſucceſs of Chymical operations.

As it is exceeding difficult to govern and moderate the action of fire, when the veſſels in which any operation is performed are immediately expoſed to it, Chymiſts have contrived to convey heat to their veſſels, in nice operations, through different mediums, which they place occaſionally between thoſe veſſels and the fire.

Thoſe intermediate ſubſtances in which they plunge their veſſels are called Baths. They are either fluid or ſolid: the fluid baths are water or its vapours. When the diſtilling veſſel is ſet in water, the bath is called *Balneum mariæ*, or the *Water-bath*; and the greateſt degree of heat of which it is ſuſceptible is that of boiling water. When the veſſel is expoſed only to the vapours which exhale from water, this forms the *Vapour-bath*; the heat of which is nearly the ſame with that of the *Balneum mariæ*. Theſe baths are uſeful for diſtilling eſſential oils, ardent ſpirits, ſweet-ſcented waters; in a word, all ſuch ſubſtances as cannot bear a greater heat without prejudice either to their odour, or to ſome of their other qualities.

Baths may alſo be made of any other fluids, ſuch as oils, mercury, *&c.* which are capable of receiving and communicating much more heat; but they are very ſeldom uſed. When a more conſiderable degree of heat is required, a bath is prepared of any ſolid matter reduced to a fine powder; ſuch as ſand, aſhes, filings of iron, *&c.* The heat of theſe baths may be puſhed ſo far as to make the bottom of the veſſel become faintly red. By plunging a thermometer into the bath, by the ſide of the veſſel, it is eaſy to obſerve the preciſe degree of heat applied to the ſubſtance on which you are working. It is neceſſary that the thermometers employed on this occaſion be conſtructed on good principles, and ſo contrived as to be eaſily compared with thoſe of the moſt celebrated natural philoſophers. Thoſe of the illuſtrious Réaumur are moſt uſed and beſt known, ſo that it would not be amiſs to give them the preference. When a greater heat is required than any of thoſe baths can give, the veſſels muſt be ſet immediately on live coals, or in a flaming fire: this is called working with a naked fire; and in this caſe it is much more difficult than in the other to determine the degrees of heat.

There are ſeveral ways of applying a naked fire. When the heat or flame is reflected upon the upper part of the veſſel which is expoſed to the fire, this is called a Reverberated heat. A Melting heat is that which is ſtrong enough to fuſe moſt bodies. A Forging heat is that of a fire which is forcibly excited by the conſtant blaſt of a pair of bellows, or more.

There is alſo another ſort of fire which ſerves very commodiouſly for many operations, becauſe it does not require to be fed or frequently mended: this is afforded by a lamp with one or more wicks, and may be called a Lamp-heat. It is ſcarce ever employed but to heat baths, in operations which require a gentle and long continued warmth: if it hath any fault, it is that of growin gradually hotter.

All theſe different ways of applying fire requi furnaces of different conſtructions: we ſhall therefore deſcribe ſuch as are of principal and moſt neceſſary uſe.

Furnaces muſt be divided into different parts or ſtories, each of which has its particular uſe and name.

The lower part of the furnace deſigned for receiving the aſhes, and giving paſſage to the air, is called the aſh-hole. The aſh-hole is terminated above by a grate, the uſe of which is to ſupport the coals and wood, which are to be burnt thereon: this part is called the fire-place. The fire-place is in like manner terminated above by ſeveral iron bars, which lie quite a-croſs it from right to left, in lines parallel to each other: the uſe of theſe bars is to ſuſtain the veſſels in which the operations are to be performed. The ſpace above theſe bars to the top of the furnace is the upper ſtory, and may be called the laboratory of the furnace. Laſtly, ſome furnaces are quite covered above, by means of a kind of vaulted roof called the dome.

Furnaces have moreover ſeveral apertures: one of theſe is at the aſh-hole, which gives paſſage to the air, and through which the aſhes that fall through the grate are raked out; this aperture is called the aſh-hole door: another is at the fire place, through which the fire is ſupplied with fewel, as occaſion requires; this is called the mouth or door of the fire place, or the ſtoke-hole: there is a third in the upper ſtory, through which the neck of the veſſel paſſes; and a fourth in the dome for carrying off the fuliginoſities of combuſtible matters, which is called the chimney.

To conclude, there are ſeveral other openings in the ſeveral parts of the furnace, the uſe whereof is to admit the air into thoſe places, and alſo, as they can be eaſily ſhut, to incite or ſlacken the activity of the fire, and ſo to regulate it; which has procured them the title of regiſters. All the other openings of the furnace ſhould be made to ſhut very cloſe, the better to aſſiſt in governing the fire; by which means they likewiſe do the office of regiſters.

In order to our forming a juſt and general idea of the conſtruction of furnaces, and of the diſpoſition of the ſeveral apertures in them, with a view to increaſe or diminiſh the activity of the fire, it will be proper to lay down, as our ground-work, certain principles of natural philoſophy, the truth of which is demonſtrated by experience.

And firſt, every body knows that combuſtible matters will not burn or conſume unleſs they have a free communication with the air; inſomuch that if they be deprived thereof, even when burning moſt rapidly, they will be extinguiſhed at once: that conſequently combuſtion is greatly promoted by the frequent acceſſion of freſh air, and that a ſtream of air, directed ſo as to paſs with impetuoſity through burning fewel, excites the fire to the greateſt poſſible activity.

Secondly, it is certain that the air which touches or comes near ignited bodies is heated, rarefied, and rendered lighter than the air about it, that is, further diſtant from the center of heat; and conſequently that this air ſo heated and become lighter is neceſſarily determined thereby to aſcend and mount aloft, in order to make room for that which is leſs heated and not ſo light, which by its weight and elaſticity tends to occupy the place quitted by the other. Another conſequence hereof is, that if fire be kindled in a place encloſed every where but above and below, a current of air will be formed in that place, running in a direction from the bottom to the top; ſo that if any light bodies be applied to the opening below, they will be carried up towards the fire; but, on the contrary, if they be held at the opening above, they will be impelled by a force which will drive them up and carry them away from the fire.

Thirdly and laſtly, it is a truth demonſtrated in hydraulics that the velocity of a given quantity of any fluid, determined to flow in any direction whatever, is ſo much the greater the narrower the channel is to which that fluid is confined; and conſequently that the velocity of a fluid will be increaſed by making it run from a wider through a narrower paſſage.

Theſe principles being eſtabliſhed, it is eaſy to apply them to the conſtruction of furnaces. Firſt, if a fire be kindled in the fire-place of a furnace, which is open on all ſides, it burns nearly as if it were in the open air. It has with the ſurrounding air a free communication; ſo that freſh air is continually admitted to facilitate the entire combuſtion of the inflammable matters employed as fewel. But there being nothing to determine that air to paſs with rapidity through the fire in this caſe, it does not at all augment the activity thereof, but ſuffers it to waſte away quietly.

Secondly, if the aſh-hole or dome of a furnace in which a fire is burning be ſhut quite cloſe, then there is no longer any free communication between the air and the fire: if the aſh-hole be ſhut, the air is debarred from having free acceſs to the fire; if the dome be ſtopt, the egreſs of the air rarefied by the fire is prevented; and conſequently the fire muſt in either caſe burn very faintly and ſlowly, gradually die away, and at laſt go quite out.

Thirdly, if all the openings of the furnace be wholly cloſed, it is evident that the fire will be very quickly extinguiſhed.

Fourthly, if only the lateral openings of the fire-place be ſhut, leaving the aſh-hole and upper part of the furnace open; it is plain that the air entering by the aſh-hole will neceſſarily be determined to go out at top, and that conſequently a current of air will be formed, which will paſs through the fire and make it burn briſkly and vigorouſly.

Fifthly, if both the aſh-hole and the upper ſtory of the furnace be of ſome length, and form canals either cylindric or priſmatic, then the air being kept in the ſame direction through a longer ſpace, the courſe of its ſtream will be both ſtronger and better determined, and conſequently the fire will be more animated by it.

Sixthly and laſtly, if the aſh-hole and the upper part of the furnace, inſtead of being cylindric or priſmatic canals, have the form of truncated cones or pyramids, ſtanding on their baſes, and ſo ordered that the upper opening of the aſh-hole, adjoining to the fire-place, may be wider than the baſe of the ſuperiour cone or pyramid, then the ſtream of air, being forced to paſs inceſſantly from a larger channel through a ſmaller, muſt be conſiderably accelerated, and procure to the fire the greateſt activity which it can receive from the make of a furnace.

The materials fitteſt for building furnaces are, 1. Bricks, joined together with potters clay mixed with ſand and moiſtened with water. 2. Potters clay mingled with potſherds, moiſtened with water, and baked in a violent fire. 3. Iron; of which all furnaces may be made, with this precaution, that the inſide be provided with a great many prominent points, as faſtenings for a coat of earth, with which the internal parts of the furnace muſt neceſſarily be covered to defend it from the action of the fire.

The reverberating furnace is one of thoſe that are moſt employed in Chymiſtry: it is proper for diſtillations by the retort, and ſhould be conſtructed in the following manner.

Firſt, the uſe of the aſh-hole being, as was ſaid, to give paſſage to the air and to receive the aſhes, no bad conſequence can attend its being made pretty high: it may have from twelve to twenty or twenty-four inches in heighth. Its aperture ſhould be wide enough to admit billets of wood when a great fire is to be made.

Secondly, the aſh-hole muſt be terminated at its upper part by an iron grate, the bars of which ſhould be very ſubſtantial, that they may reſiſt the action of the fire: this grate is the bottom of the fire-place, and deſtined to ſupport the coals. In the lateral part of the fire-place, and nearly about the ſame heighth with the grate, there ſhould be a hole of ſuch a ſize that it may eaſily admit charcoal, as well as little tongs and ſhovels for managing the fire. This aperture or mouth of the fire-place ſhould be perpendicularly over the mouth of the aſh-hole.

Thirdly, from ſix to eight or ten inches high above the grate over the aſh-hole, little apertures muſt be made in the walls of the furnace, of eight or ten lines in diameter, an inch from one another, and thoſe in one ſide muſt be diametrically oppoſite to thoſe in the other. The uſe of theſe holes is to receive bars of iron for the retort to reſt on; which ſhould be, as I ſaid, at different heighths, in order to accommodate retorts of different ſizes. At the upper extremity of this part of the furnace, which reaches from the iron bars to the top, the heighth whereof ſhould be ſomewhat leſs than the width of the furnace, muſt be cut a ſemi-circular aperture for the neck of the retort to come through. This hole muſt by no means be over the doors of the fire-place and aſh-hole; for then, as it gives paſſage to the neck of the retort, it muſt of courſe be oppoſite to the receiver, and in that caſe the receiver itſelf would ſtand over againſt thoſe two apertures; which would be attended with this double inconvenience, that the receiver would not only grow very hot, but greatly embarraſs the operator, whoſe free acceſs to the fire-place and aſh-hole would be thereby obſtructed. It is proper therefore that the ſemi-circular cut we are ſpeaking of be ſo placed that when the greateſt ballons are luted to the retort they may leave an open paſſage to the fire-place and aſh-hole.

Fourthly, in order to cover in the laboratory of the reverberating furnace, there muſt be a roof made for it in the form of a cupola, or concave hemiſphere, having the ſame diameter as the furnace. This dome ſhould have a ſemicircular cut in its rim anſwering to that above-directed to be made in the upper extremity of the furnace, ſo that, when adjuſted to each other, the two together may form a circular hole for the neck of the retort to paſs through. At the top of this dome there muſt alſo be a circular hole of three or four inches diameter, carrying a ſhort tapering funnel of the ſame diameter, and three inches high, which will ſerve for a chimney to carry off all fuliginoſities, and accelerate the current of the air. This paſſage may be ſhut at pleaſure with a flat cover. Moreover, as it is neceſſary that the dome ſhould be taken off and put on with eaſe, it ſhould have two ears or handles for that purpoſe: a portative or moveable furnace ſhould alſo have a pair of handles fixed oppoſite to each other between the aſh-hole and the fire-place.

Sixthly and laſtly, a conical canal muſt be provided of about three foot long, and ſufficiently wide at its lower end to admit the funnel of the aperture at the top of the dome. This conical tube is to be applied to the dome when the fire is required to be extremely active: it tapers gradually from its baſe upwards, and breaks off as if truncated at top, where it ſhould be about two inches wide.

Beſides the apertures already mentioned as neceſſary to a reverberating furnace, there muſt alſo be many other ſmaller holes made in its aſh-hole, fire-place, laboratory, and dome, which muſt all be ſo contrived as to be eaſily opened and ſhut with ſtopples of earth: theſe holes are the regiſters of the furnace, and ſerve to regulate the activity of the fire according to the principles before laid down.

When the action of the fire is required to be exactly uniform and very briſk, it is neceſſary to ſtop carefully with moiſt earth all the little chinks in the juncture of the dome with the furnace, between the neck of the retort and the circular hole through which it paſſes, and which it never fills exactly, and laſtly, the holes which receive the iron bars that ſuſtain the retort.

It is proper to have in a laboratory ſeveral reverberating furnaces of different magnitudes; becauſe they muſt be proportioned to the ſize of the retorts employed. The retort ought to fill the furnace, ſo as to leave only the diſtance of an inch between it and the inſide of the furnace.

Yet when the retort is to be expoſed to a moſt violent fire, and eſpecially when it is required that the heat ſhall act with equal force on all parts of the furnace, and as ſtrongly on its vault as on its bottom, a greater diſtance muſt be left between the retort and the inſide of the furnace; for then the furnace may be filled with coals, even to the upper part of the dome. If moreover ſome pieces of wood be put into the aſh-hole, the conical canal fitted on to the funnel of the dome, and all the apertures of the furnace exactly cloſed, except the aſh-hole and the chimney, the greateſt heat will then be excited that this furnace can produce.

The furnace now deſcribed may alſo be employed in many other chymical operations. If the dome be laid aſide, an alembic may very well be placed therein: but then the ſpace, which will be left between the body of the alembic and the top of the upper part of the furnace, muſt be carefully filled up with Windſor-loam moiſtened; for without that precaution the heat would ſoon reach the very head, which ought to be kept as cool as poſſible, in order to promote the condenſation of the vapours. On this occaſion therefore it will be proper to leave no holes open in the fire-place, but the lateral ones; of which alſo thoſe over-againſt the receiver muſt be ſtopped.

A pot or broad-brimmed earthen pan may be placed over this furnace, and being ſo fitted to it as to cloſe the upper part thereof accurately, and filled with ſand, may ſerve for a ſand-heat to diſtill with.

The bars deſigned to ſupport diſtilling veſſels being taken out, a crucible may ſtand therein, and many operations be performed that do not require the utmoſt violence of fire. In a word, this furnace is one of the moſt commodious that can be, and more extenſively uſeful than any other.

The melting furnace is deſigned fot applying the greateſt force of heat to the moſt fixed bodies, ſuch as metals and earths. It is never employed in diſtilling: it is of no uſe but for calcination and fuſion; and conſequently need not admit any veſſels but crucibles.

The aſh-hole of this furnace differs from that of the reverberating furnace only in this, that it muſt be higher, in order to raiſe the fire-place to a level with the artiſt's hand; becauſe in that all the operations of this furnace are performed. The aſh-hole therefore muſt be about three foot high: and this heighth procures it moreover the advantage of a good draught of air. For the ſame reaſon, and in conſequence of the principles we laid down, it ſhould be ſo built that its width leſſening inſenſibly from the bottom to the top, it may be narrower where it opens into the fire-place than any where below.

The aſh-hole is terminated at its upper end, like that of the reverberating furnace, by a grate which ſerves for the bottom of the fire-place, and ought to be very ſubſtantial that it may reſiſt the violence of the fire. The inſide of this furnace is commonly an elliptic curve; becauſe it is demonſtrated by mathematicians that ſurfaces having that curvature reflect the rays of the ſun, or of fire, in ſuch a manner that meeting in a point, or a line, they produce there a violent heat. But to anſwer this purpoſe thoſe ſurfaces muſt be finely poliſhed; an advantage hardly procurable to the internal ſurface of this furnace, which can be made of nothing but earth: beſides, if it were poſſible to give it a poliſh, the violent action of the fire that muſt be employed in this furnace would preſently deſtroy it. Yet the elliptical figure muſt not be entirely diſregarded: for, if care be taken to keep the internal ſurface of the furnace as ſmooth as poſſible, it will certainly reflect the heat pretty ſtrongly, and collect it about the center.

The fire-place of this furnace ought to have but four apertures.

Firſt, that of the lower grate, which communicates with the aſh-hole.

Secondly, a door in its fore-ſide, through which may be introduced coals, crucibles, and tongs for managing them: this aperture ſhould be made to ſhut exactly with a plate of iron, having its inſide coated with earth, and turning on two hinges fixed to the furnace.

Thirdly, over this door a hole ſlanting downwards towards the place where the crucible is to ſtand. The uſe of this hole is to give the operator an opportunity of examining the condition of the matters contained in his crucible, without opening the door of the fire-place: this hole ſhould be made to open and ſhut eaſily, by means of a ſtopple of earth.

Fourthly, a circular aperture of about three inches wide in the upper part or vault of the furnace, which ſhould gradually leſſen and terminate, like that of the dome of the reverberating furnace, in a ſhort conical funnel of about three inches long, and fitted to enter the conical pipe before deſcribed, which is applied when the activity of the fire is to be increaſed.

When this furnace is to be uſed, and a crucible to be placed in it, care muſt be taken to ſet on the grate a cake of baked earth ſomewhat broader than the foot of the crucible. The uſe of this ſtand is to ſupport the crucible, and raiſe it above the grate, for which purpoſe it ſhould be two inches thick. Were it not for this precaution the bottom of the crucible, which would ſtand immediately on the grate, could never be thoroughly heated, becauſe it would be always expoſed to the ſtream of cold air which enters by the aſh-hole. Care ſhould alſo be taken to heat this earthen bottom red-hot before it be placed in the furnace, in order to free it from any humidity, which might otherwiſe happen to be driven againſt the crucible during the operation, and occaſion its breaking.

We omitted to take notice in ſpeaking of the aſh-hole that, beſides its door, it ſhould have about the middle of its heighth a ſmall hole, capable of receiving the noſel of a good perpetual bellows, which is to be introduced into it and worked, after the door is exactly ſhut, when it is thought proper to excite the activity of the fire to the utmoſt violence.

The forge is only a maſs of bricks of about three foot high, along whoſe upper ſurface is directed the noſe or pipe of a pair of large perpetual bellows, ſo placed that the operator may eaſily blow the fire with one hand. The coals are laid on the hearth of the forge near the noſe of the bellows; they are confined, if neceſſary, to prevent their being carried away by the wind of the bellows, within a ſpace incloſed by bricks; and then by pulling the bellows the fire is continually kept up in its greateſt activity. The forge is of uſe when there is occaſion to apply a great degree of heat ſuddenly to any ſubſtance, or when it is neceſſary that the operator be at liberty to handle frequently the matters which he propoſes to fuſe or calcine.

The cupelling furnace is that in which gold and ſilver are purified, by the means of lead, from all alloy of other metallic ſubſtances. This furnace muſt give a heat ſtrong enough to vitrify lead, and therewith all the alloy which the perfect metals may contain. This furnace is to be built in the following manner.

Firſt, of thick iron-plates, or of ſome ſuch compoſition of earth as we recommended for the conſtruction of furnaces, muſt be formed a hollow quadrangular priſm whoſe ſides may be about a foot broad, and from ten to eleven inches high; and extending from thence upwards may converge towards the top, ſo as to form a pyramid truncated at the heighth of ſeven or eight inches, and terminated by an aperture of the width of ſeven or eight inches every way. The lower part of the priſm is terminated and cloſed by a plate of the ſame materials of which the furnace is conſtructed.

Secondly, in the fore-ſide or front of this priſm there is an opening of three or four inches in heighth by five or ſix inches in breadth: this opening, which ſhould be very near the bottom, is the door of the aſh-hole. Immediately over this opening is placed an iron grate, the bars of which are quadrangular pryſms of half an inch ſquare, laid parrallel to each other; and about eight or nine inches aſunder, and ſo diſpoſed that two of their angles are laterally oppoſite, the two others looking one directly upwards and the other downwards. As in this ſituation the bars of the grate preſent to the fire-place very oblique ſurfaces, the aſhes and very ſmall coals do not accumulate between them, or hinder the free entrance of the air from the aſh-hole. This grate terminates the aſh-hole at its upper part, and ſerves for the bottom of the fire-place.

Thirdly, three inches, or three and a half, above the grate, there is in the fore-ſide of the furnace another opening terminated by an arch for its upper part, which conſequently has the figure of a ſemicircle: it ought to be four inches wide at bottom, and three inches and an half high at its middle. This opening is the door of the fire place; yet it is not intended for the ſame uſes as the door of the fire-place in other furnaces: the purpoſe for which it is actually deſtined ſhall be explained when we come to ſhew how the furnace is to be uſed. An inch above the door of the fire-place, ſtill in the foreſide of the furnace, are two holes of about an inch diameter, and at the diſtance of three inches and a half from each other, to which anſwer two other holes of the ſame ſize, made in the hinder part, directly oppoſite to theſe. There is moreover a fifth hole of the ſame width about an inch above the door of the fire-place. The deſign of all theſe holes ſhall be explained when we deſcribe the manner in which theſe furnaces are to be uſed.

Fourthly, the fore-part of the furnace is bound by three iron braces, one of which is fixed juſt below the door of the aſh-hole; the ſecond occupies the whole ſpace between the aſh-hole door and the door of the fire-place, and has two holes in it, anſwering to thoſe which we directed to be made in the furnace itſelf about this place; and the third is placed immediately over the door of the fire-place. Theſe braces muſt extend from one corner of the front of the furnace to the other, and be faſtened thereto with iron pins, in ſuch a manner that their ſides next to the doors may not lie quite cloſe to the body of the furnace, but form a kind of grooves for the iron plates to ſlide in, that are deſigned to ſhut the two doors of the furnace when it is neceſſary. Each of theſe iron plates ſhould have a handle, by which it may be conveniently moved; and to each door there ſhould be two plates, which meeting each other, and joining exactly in the middle of the door-place, may ſhut it very cloſe. Each of the two plates belonging to the door of the fire-place ought to have a hole in its upper part; one of theſe holes ſhould be a ſlit of about two lines wide, and half an inch long; the other may be a ſemi-circular opening of one inch in heighth and two in breadth. Theſe holes ſhould be placed ſo that neither of them may open into the fire-place when the two plates are joined together in the middle of the door to ſhut it cloſe.

Fifthly, to terminate the furnace above, there muſt be a pyramid formed of the ſame materials with the furnace, hollow, quadrangular, three inches high on a baſe of ſeven inches, which baſe muſt exactly fit the upper opening of the furnace: the top of this pyramidal cover muſt end in a tube of three inches in diameter and two in heighth, which muſt be almoſt cylindrical, and yet a little inclining to the conical form. This tube ſerves, as in the furnaces already deſcribed, to carry the conical funnel, which is fitted to the upper part when a fire of extraordinary activity is wanted.

The furnace thus conſtructed is fit to ſerve all the purpoſes for which it is deſigned : yet before it can be uſed another piece muſt be provided, which, though it does not properly belong to the furnace, is nevertheleſs neceſſary in all the operations performed by it ; and that is a piece contrived to contain the cupels, or other veſſels which are to be expoſed to the fire in this furnace. It is called a Muffle, and is made in the following manner.

On an oblong ſquare, of four inches in breadth, and ſix or ſeven in length, a concave ſemi-cylinder is erected, in the form of a vault, which makes a ſemi-circular canal, open at both ends. One of theſe is almoſt entirely cloſed, except that near the bottom two ſmall ſemi-circular holes are left. In each of its ſides likewiſe two ſuch holes are made, and the other end is left quite open.

The Muffle is intended to bear and communicate the fierceſt heat ; and therefore it muſt be made thin, and of an earth that will reſiſt the violence of fire, ſuch as that of which crucibles are made. The Muffle being thus conſtructed, and then well baked, is fit for uſe.

When it is to be uſed it muſt be put into the furnace by the upper opening, and ſet upon two iron bars, introduced through the holes made for that purpoſe below the door of the fire-place. The Muffle muſt be placed on theſe bars in the fire-place, in ſuch a manner that its open end ſhall ſtand next to and directly againſt the door of the fire-place, and may be joined to it with lute. Then the cupels are ranged in it, and the furnace is filled up, to the heighth of two or three inches above the Muffle, with ſmall coals not bigger than a walnut, to the end that they may lie cloſe round the Muffle, and procure it an equal heat on every ſide. The chief uſe of the Muffle is to prevent the coals and aſhes from falling into the cupels, which would be very prejudicial to the operations carrying on in them: for the lead would not vitrify as it ought, becauſe the immediate contact of the coals would continually reſtore its phlogiſton; or elſe the glaſs of lead, which ought to penetrate and paſs through the cupels, would be rendered incapable of ſo doing; becauſe the aſhes mixing therewith would give it ſuch a conſiſtence and tenacity as would deſtroy that property, or at leaſt conſiderably leſſen it. The openings therefore, which are left in the lower part of the Muffle, ſhould not be ſo high as to admit coals or aſhes to get into the cupels; the uſe of them is to procure an eaſier paſſage for the heat and the air to thoſe veſſels. The Muffle is left quite open in its fore-part, that the operator may be at liberty to examine what paſſes in the cupels, to ſtir their contents, to remove them from one place to another, to convey new matters into them, &c. and alſo to promote the free acceſs of the air, which muſt concur with the fire towards the evaporation neceſſary to the vitrification of lead; which air, if freſh were not often enough admitted, would be incapable of producing that effect; becauſe it would ſoon be loaded with ſuch a quantity of vapours that it could not take up any more.

The government of the fire in this furnace is founded on the general principles above laid down for all furnaces. Yet as there are ſome little differences, and as it is very eſſential to the ſucceſs of the operations for which this furnace is intended, that the artiſt ſhould be abſolutely maſter of his degree of heat, we ſhall in few words ſhew how that may be raiſed or lowered.

When the furnace is filled with coals and kindled, if the door of the aſh-hole be ſet wide open, and that of the fire-place ſhut very cloſe, the force of the fire is encreaſed; and if moreover the pyramidal cover be put on the top, and the conical funnel added to it, the fire will become ſtill more fierce.

Seeing the matters contained in this furnace are encompaſſed with fire on all ſides, except in the fore part oppoſite to the door of the fire-place, and as there are occaſions which require that the force of the fire ſhould be applied to this part alſo, an iron box, of the ſhape and ſize of the door, hath been contrived to anſwer that purpoſe. This box is filled with lighted coals, and applied immediately to the door-place, by which means the heat there is conſiderably augmented. This help may be made uſe of at the beginning of the operation, in order to accelerate it, and bring the heat ſooner to the deſired degree; or in caſe a very fierce heat be required; or at a time when the air being hot and moiſt will not make the fire burn with the neceſſary vigour.

The heat may be leſſened by removing the iron box, and ſhutting the door of the fire-place quite cloſe. It may be ſtill further and gradually diminiſhed, by taking off the conical funnel from the top; by ſhutting the door of the fire-place with one of its plates only, that which has the leaſt, or that which has the greateſt aperture in it; by taking off the pyramidal cover; by ſhutting the aſh-hole door wholly or in part; and laſtly, by ſetting the door of the fire-place wide open: but, in this laſt caſe, the cold air penetrates into the cavity of the Muffle, and refrigerates the cupels more than is almoſt ever neceſſary. If it be obſerved, during the operation, that the Muffle grows cold in any particular part, it is a ſign there is a vacuity left by the coals in that place: in this caſe an iron wire muſt be thruſt into the furnace, through the hole which is over the door of the fire-place, and the coals ſtirred therewith, ſo as to make them fall into their places and fill up the vacant interſtices.

It is proper to obſerve that, beſides what has been ſaid concerning the ways of increaſing the activity of the fire in the cupelling furnace, ſeveral other cauſes alſo may concur to procure to the matters contained in the Muffle a greater degree of heat: for example, the ſmaller the Muffle is; the wider and more numerous the holes in it are; the nearer to its bottom, or further end, the cupels are placed; the more will the matters therein contained be affected with heat.

Beſides the operations to be performed by the cupel, this furnace is very uſeful, and even neceſſary, for many chymical experiments; ſuch, for inſtance, as thoſe relating to ſundry vitrifications and enamelling. As it is pretty low, the beſt way is to place it, when it is to be uſed, on a baſe of brick-work that may raiſe it to a level with the operator's hand.

A lamp-furnace is exceeding uſeful for all operations that require only a moderate, but long continued, degree of heat. The furnace for working with a lamp-heat is very ſimple: it conſiſts only of a hollow cylinder, from fifteen to eighteen inches high, and five or ſix in diameter, having at its bottom an aperture large enough for a lamp to be introduced and withdrawn with eaſe. The lamp muſt have three or four wicks, to the end that by lighting more or fewer of them a greater or leſs degree of heat may be produced. The body of the furnace muſt moreover have ſeveral ſmall holes in it, in order to ſupply the flame of the lamp with air enough to keep it alive.

On the top of this furnace ſtands a baſon five or ſix inches deep, which ought to fill the cavity of the cylinder exactly, and to be ſupported at its circumference by a rim which may entirely cover and cloſe the furnace: the uſe of this baſon is to contain the ſand through which the lamp-heat is uſually conveyed.

Beſides this there muſt be a kind of cover or dome made of the ſame material with the furnace, and of the ſame diameter with the ſand-bath, without any other opening than a hole, nearly circular, cut in its lower extremity. This dome is a ſort of reverberatory, which ſerves to confine the heat and direct it towards the body of the retort; for it is uſed only when ſomething is to be diſtilled in a veſſel of this faſhion; and then the hole at its bottom ſerves for a paſſage to the neck of the retort. This dome ſhould have an ear or handle, for the conveniency of putting it on and taking it off with eaſe.

Of Lutes.

CHYMICAL veſſels, eſpecially ſuch as are made of glaſs, and the earthen veſſels commonly called ſtone-ware, are very ſubject to break when expoſed to ſudden heat or cold; whence it comes that they often crack when they begin to heat, and alſo when being very hot they happen to be cooled, either by freſh coals thrown into the furnace, or by the acceſs of cold air. There is no way to prevent the former of theſe accidents, but by taking the pains to warm your veſſel very ſlowly, and by almoſt inſenſible degrees. The ſecond may be avoided by coating the body of the veſſel with a paſte or lute, which being dried will defend it againſt the attacks of cold.

The fitteſt ſtuff for coating veſſels is a compoſition of fat earth, Windſor-loam, fine ſand, filings of iron, or powdered glaſs, and chopped cow's hair, mixed and made into a paſte with water. This lute ſerves alſo to defend glaſs veſſels againſt the violence of the fire, and to prevent their melting eaſily.

In almoſt all diſtillations it is of great conſequence, as hath been ſaid, that the neck of the diſtilling veſſel be exactly joined with that of the receiver into which it is introduced, in order to prevent the vapours from eſcaping into the air and ſo being loſt: and this junction is effected by means of a lute.

A few ſlips of paper applied round the neck of the veſſels with common ſize will be ſufficient to keep in ſuch vapours as are aqueous, or not very ſpirituous.

If the vapours are more acrid and more ſpirituous, recourſe may be had to ſlips of bladder long ſteeped in water, which containing a ſort of natural glue cloſe the junctures of the veſſels very well.

If it be required to confine vapours of a ſtill more penetrating nature, it will be proper to employ a lute that quickly grows very hard; particularly a paſte made with quick-lime and any ſort of gelly, whether vegetable or animal; ſuch as the white of an egg, ſtiff ſize, &c. This is an excellent lute and not eaſily penetrated. It is alſo uſed to ſtop any cracks or fractures that happen to glaſs veſſels. But it is not capable of reſiſting the vapours of mineral acid ſpirits, eſpecially when they are ſtrong and ſmoking: for that purpoſe it is neceſſary to incorporate the other ingredients thoroughly with fat earth ſoftened with water; and even then it frequently happens that this lute is penetrated by acid vapours, eſpecially thoſe of the ſpirit of ſalt, which of all others are confined with the greateſt difficulty.

In ſuch caſes its place may be ſupplied with another, which is called Fat Lute, becauſe it is actually worked up with fat liquors. This lute is compoſed of a very fine cretaceous earth, called tobacco-pipe clay, moiſtened with equal parts of the drying oil of lint-ſeed, and a varniſh made of amber and gum copal. It muſt have the conſiſtence of a ſtiff paſte. When the joints of the veſſels are cloſed up with this lute, they may, for greater ſecurity, be covered over with ſlips of linnen ſmeared with the lute made of quick-lime and the white of an egg.

Chymical veſſels are liable to be broken in an operation by other cauſes beſides the ſudden application of heat or cold. It frequently happens that the vapours of the matters expoſed to the action of fire ruſh out with ſuch impetuoſity, and are ſo elaſtic, that finding no paſſage through the lute with which the joints of the veſſels are cloſed, they burſt the veſſels themſelves, ſometimes with exploſion and danger to the operator.

To prevent this inconvenience, it is neceſſary that in every receiver there be a ſmall hole, which being ſtopped only with a little lute may eaſily be opened and ſhut again as occaſion requires. It ſerves for a vent-hole to let out the vapours, when the receiver begins to be too much crowded with them. Nothing but practice can teach the artiſt when it is requiſite to open this vent. If he hits the proper time, the vapours commonly ruſh out with rapidity, and a conſiderable hiſſing noiſe; and the vent ſhould be ſtopped again as ſoon as the hiſſing begins to grow faint. The lute employed to ſtop this ſmall hole ought always to be kept ſo ductile, that by taking the figure of the hole exactly it may entirely ſtop it. Beſides, if it ſhould harden upon the glaſs, it would ſtick ſo faſt that it would be very difficult to remove it without breaking the veſſel. This danger is eaſily avoided by making uſe of the fat lute, which continues pliant for a long time, when it is not expoſed to an exceſſive heat.

This way of ſtopping the vent-hole of the receiver has yet another advantage: for if the hole be of a proper width, as a line and half, or two lines, in diameter, then when the vapours are accumulated in too great a quantity, and begin to make a great effort againſt the ſides of the receiver, they puſh up the ſtopple, force it out, and make their way through the vent-hole : ſo that by this means the breaking of the veſſels may always be certainly prevented. But great care muſt be taken that the vapours be not ſuffered to eſcape in this manner, except when abſolute neceſſity requires it ; for it is generally the very ſtrongeſt and moſt ſubtile part of a liquor which is thus diſſipated and loſt.

Heat being the chief cauſe that puts the elaſticity of the vapours in action, and prevents their condenſing into a liquor, it is of great conſequence in diſtillation that the receiver be kept as cool as poſſible. With this view a thick plank ſhould be placed between the receiver and the body of the furnace, to intercept the heat of the latter, and prevent its reaching the former. As the vapours themſelves riſe very hot from the diſtilling veſſel, they ſoon communicate their heat to the receiver, and eſpecially to its upper part, againſt which they ſtrike firſt. For this reaſon it is proper that linen cloths dipt in very cold water be laid over the receiver, and frequently ſhifted. By this means the vapours will be conſiderably cooled, their elaſticity weakened, and their condenſation promoted.

By what hath been ſaid in this firſt part, concerning the properties of the principal agents in Chymiſtry, the conſtruction of the moſt neceſſary veſſels and furnaces, and the manner of uſing them, we are ſufficiently prepared for proceeding directly to the operations, without being obliged to make frequent and long ſtops, in order to give the neceſſary explanations on thoſe heads.

Nevertheleſs we ſhall take every proper occaſion to extend the theory here laid down, and to improve it by the addition of ſeveral particulars, which will find their places in our treatiſe of Chymical Operations.

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ELEMENTS

OF THE

PRACTICE of CHYMISTRY;

WHEREIN

The Fundamental Operations are deſcribed, and illuſtrated by Obſervations on each Proceſs.

ELEMENTS OF THE PRACTICE of CHYMISTRY.

INTRODUCTION.

AS the Elements of the Theory of Chymiſtry, delivered in the former part of this work, were intended for the uſe of perſons ſuppoſed to be altogether unacquainted with the art, they could not properly admit of any thing more than fundamental principles, ſo diſpoſed as conſtantly to lead from the ſimple to the compound, from things known to things unknown: for which reaſon I could not therein obſerve the uſual order of Chymical Decompoſition, which is not ſuſceptible of ſuch a method. I therefore ſuppoſed all the analyſes made, and bodies reduced to their ſimpleſt principles; to the end that, by obſerving the chief properties of thoſe primary elements, we might be enabled to trace them through their ſeveral combinations, and to form ſome ſort of judgment *a priori* of the qualities of ſuch compounds as may reſult from their junctions.

But this latter part is of a different nature. It is a Practical Treatiſe, intended to contain the manner of performing the principal Operations of Chymiſtry; the operations which ſerve as ſtandards for regulating all the reſt, and which confirm the funmental truths laid down in the Theory.

As theſe operations conſiſt almoſt wholly of analyſes and decompoſitions, there can be no doubt concerning the order proper to be obſerved in giving an account of them: it evidently coincides with that of the analyſis itſelf.

But as all bodies, which are the ſubjects of Chymical operations, are divided by nature into three claſſes or kingdoms, the mineral, the vegetable, and the animal, the analyſis thereof may naturally be divided into three branches: ſome difference may alſo ariſe from the different order in which theſe three may be treated of.

As the reaſons aſſigned for beginning with one kingdom rather than with another have never been thoroughly canvaſſed, and may perhaps ſeem equally good when viewed in a particular light, Chymical writers differ in their opinions on this point. For my part, without entering into a diſcuſſion of the motives which have determined others to follow a different order, I ſhall only produce the reaſons that led me to begin with the mineral kingdom, to examine the vegetable in the ſecond place, and to conclude with the animal.

Firſt then, ſeeing vegetables draw their nouriſhment from minerals, and animals derive theirs from vegetables, the bodies which conſtitute theſe three kingdoms ſeem to be generated the one by the other, in a manner that determines their natural rank.

Secondly, this diſpoſition procures us the advantage of tracing the principles, from their ſource in the mineral kingdom, down to the laſt combinations into which they are capable of entering, that is, into animal matters; and of obſerving the ſucceſſive alterations they undergo in paſſing out of one kingdom into another.

Thirdly and laſtly, I look upon the analyſis of minerals to be the eaſieſt of all; not only becauſe they conſiſt of fewer principles than vegetables and animals, but alſo becauſe almoſt all of them are capable of enduring the moſt violent action of fire, when that is neceſſary to their decompoſition, without any conſiderable change or diminution of their principles, to which thoſe of other ſubſtances are frequently liable.

Beſides, I am not ſingular in this diſtribution of the three claſſes of bodies, which are the ſubjects of the chymical analyſis: as it is the moſt natural, it has been adopted by ſeveral authors, or rather by moſt who have publiſhed Treatiſes of Chymiſtry. But there is ſomething peculiarly my own in the manner wherein I have treated the analyſis of each kingdom. In the mineral kingdom, for inſtance, will be found a conſiderable number of operations not to be met with in other Treatiſes of Chymiſtry; the authors having probably conſidered them as uſeleſs, or in ſome meaſure foreign, to the purpoſe of elementary books, and as conſtituting together a diſtinct art. I mean the proceſſes for extracting ſaline and metallic ſubſtances from the minerals containing them.

Yet, if it be conſidered that ſalts, metals, and ſemi-metals are far from being produced by nature in a ſtate of perfection, or in that degree of purity which they are commonly ſuppoſed to have when they are firſt treated of in Books of Chymiſtry; but that, on the contrary, theſe ſubſtances are originally blended with each other, and adulterated with mixtures of heterogeneous matters, wherewith they form compound minerals; I imagine it will be allowed that the operations by which theſe minerals are decompoſed, in order to extract the metals, ſemi-metals, and other ſimpler ſubſtances, eſpecially as they are founded on the moſt curious properties of theſe ſubſtances, are ſo far from being uſeleſs or foreign to the purpoſes of an elementary treatiſe, that they are, on the contrary, abſolutely neceſſary thereto.

After I had made theſe reflections, I could not help thinking that an analyſis of minerals, which ſhould treat of ſaline and metallic ſubſtances, without

out taking any notice of the manner in which their matrices muſt be analyſed in order to extract them, would be no leſs defective, than a treatiſe of the analyſis of vegetables, in which Oils, eſſential Salts, fixed and volatile Alkalis ſhould be amply treated of, without ſaying one word of the manner of analyſing the plants from which theſe ſeveral ſubſtances are obtained. I therefore thought myſelf indiſpenſably obliged to deſcribe the manner of decompoſing every ore or mineral, before I attempted to treat of the ſaline or metallic ſubſtance which it yields.

For example: as the Vitriolic Acid, with the conſideration of which I begin my Mineral Analyſis, is originally contained in Vitriol, Sulphur, and Alum; and as theſe ſubſtances again derive their origin from the ſulphureous and ferruginous Pyrites, the firſt operations I deſcribe under this head are the proceſſes for decompoſing the Pyrites in order to extract its Vitriol, Sulphur, and Alum. I then proceed to the particular analyſis of each of theſe ſubſtances, with a view to extract their Vitriolic Acid; and afterwards deliver, in their order, the other operations uſually performed on this Acid. Thus it appears that this ſaline ſubſtance occaſions my deſcribing the analyſes of the Pyrites, Vitriol, Sulphur, and Alum. The whole of the treatiſe on minerals proceeds on the ſame plan.

The operations by which we decompoſe ores and minerals are of two ſorts: thoſe employed in working by the great, and thoſe for trying in ſmall the yield of any ore. Theſe two manners of operating are ſometimes a little different; yet in the main they are the ſame, becauſe they are founded on the ſame principles, and produce the ſame effects.

As my chief deſign was to deſcribe the operations that may be conveniently performed in a laboratory, I have preferred the proceſſes for ſmall aſſays; eſpecially as they are uſually performed with more care and accuracy than the operations in great works: and here I muſt acknowledge that I am obliged to M. Cramer's *Docimaſia*, or Art of Aſſaying, for all the operations of this kind in my analyſis of minerals. As M. Hellot's work on that ſubject did not appear till after I had finiſhed this, M. Cramer's *Docimaſia*, in which ſound Theory is joined with accurate Practice, was the beſt book of the kind I could at that time conſult. I therefore preferred it to all others; and as I have not quoted it in my analyſis of minerals, becauſe the quotations would have been too frequent, let what I ſay here ſerve for a general quotation. I have been careful to name, as often as occaſion required, the other authors whoſe proceſſes I have borrowed: it is a tribute juſtly due to thoſe who have communicated their diſcoveries to the publick.

Though I have told the reader that in my analyſis of minerals he will find the proceſſes for extracting out of each the ſaline or metallic ſubſtances contained in it, yet he muſt not expect that this book will inſtruct him in all that it is neceſſary he ſhould know to be able to determine, by an accurate aſſay, the contents of every mineral. My intention was not to compoſe a Treatiſe of Aſſaying; and I have taken in no more than was abſolutely neceſſary to make the analyſis of minerals perfectly underſtood, and to render it as complete as it ought to be in an Elementary Treatiſe. I have therefore deſcribed only the principal operations relating thereto; the operations which are fundamental, and which, as I ſaid before, are to ſerve as ſtandards for the reſt, abſtracted from ſuch additional circumſtances as are of conſequence only to the Art of Aſſaying, properly ſo called.

Such therefore as are deſirous of being fully inſtructed in that Art, muſt have recourſe to thoſe works which treat profeſſedly of the ſubject; and particularly to that publiſhed by M. Hellot: a performance moſt eſteemed by ſuch as are beſt ſkilled in Chymiſtry, and rendered ſo complete by the numerous and valuable obſervations and diſcoveries of the Author, that nothing better of the kind can be wiſhed for. I thought it proper to give theſe notices in relation to my analyſis of minerals; and ſhall now proceed to ſhew the plan of my analyſes of vegetables and of animals.

Seeing all vegetable matters are ſuſceptible of fermentation, and when analyſed after fermentation yield principles different from thoſe we obtain from them before they are fermented, I have divided them into two claſſes; the former including vegetables in their natural ſtate, before they have undergone fermentation; and the latter thoſe only which have been fermented. This analyſis opens with the proceſſes by which we extract from vegetables all the principles they will yield without the help of fire; and then follow the operations for decompoſing plants by degrees of heat, from the gentleſt to the moſt violent, both in cloſe veſſels and in the open air.

I have not made the ſame diviſion in the animal kingdom, becauſe the ſubſtances that compoſe it are ſuſceptible only of the laſt degree of fermentation, or putrefaction; and moreover the principles they yield, whether putrefied or unputrefied, are the very ſame, and differ only with regard to their proportions, and the order in which they are extricated during the analyſis.

I begin this analyſis with an examination of the milk of animals that feed wholly on vegetables; becauſe though this ſubſtance be elaborated in the body of the animal, and by that means brought nearer to the nature of animal matters, yet it ſtill retains a great ſimilitude to the vegetables from which it derives its origin, and is a ſort of intermediate ſubſtance between the vegetable and animal. Then I proceed to the analyſis of animal matters properly ſo called, thoſe which actually make a part of the animal body. I next examine the excrementitious ſubſtances, that are thrown out of the animal body as ſuperfluous and uſeleſs. And then I conclude this latter part with operations on the Volatile Alkali; a ſaline ſubſtance of principal conſideration in the decompoſition of animal matters.

Though in the general view here given of the order obſerved in this Treatiſe of Practical Chymiſtry I have mentioned only ſuch proceſſes as ſerve for analyſing bodies, yet I have alſo inſerted ſome other operations of different kinds. The book would be very defective if it contained no more: for the deſign of Chymiſtry is not only to analyſe the mixts produced by nature, in order to obtain the ſimpleſt ſubſtances of which they are compoſed, but moreover to diſcover by ſundry experiments the properties of thoſe elementary principles, and to recombine them in various manners, either with each other, or with different bodies, ſo as to reproduce the original mixts with all their properties, or even form new compounds which never exiſted in nature. In this book therefore the reader will find proceſſes for combining and recompounding, as well as for reſolving and decompoſing bodies. I have placed them next to the proceſſes for decompoſition, taking all poſſible care not to interrupt their order, or break the connection between them.

ELEMENTS OF THE PRACTICE of CHYMISTRY.

PART I.

OF MINERALS.

SECTION I.

Operations performed on Saline Mineral Subſtances.

CHAP. I.

Of the VITRIOLIC ACID.

PROCESS I.

To extract Vitriol from the Pyrites.

TAKE any quantity you pleaſe of Iron-Pyrites; leave them for ſome time expoſed to the air: they will crack, ſplit, loſe their brightneſs, and fall into powder. Put this powder into a glaſs cucurbit, and pour upon it twice its weight of hot water; ſtir the whole with a ſtick, and the liquor will grow turbid. Pour it while it is yet warm into a glaſs funnel lined with brown filtering paper; and having placed your funnel over another glaſs cucurbit, let the liquor drain into it. Pour more hot water on the powdered Pyrites, filter as before, and ſo go on, every time leſſening the quantity of water, till that which comes off the Pyrites appears to have no aſtringent vitriolic taſte.

Put all theſe waters together into a glaſs veſſel that widens upwards; ſet it on a ſand bath, and heat the liquor till a conſiderable ſmoke ariſes; but take care not to make it boil. Continue the ſame degree of fire till the ſurface of the liquor begins to look dim, as if ſome duſt had fallen into it; then ceaſe evaporating, and remove the veſſel into a cool place: in the ſpace of four and twenty hours there will be formed therein a quantity of cryſtals, of a green colour and a rhomboidal figure: theſe are Vitriol of Mars, or Copperas. Decant the remaining liquor; add thereto twice its weight of water; filter, evaporate, and cryſtallize as before; repeat theſe operations till the liquor will yield no more cryſtals, and keep by themſelves the cryſtals obtained at each cryſtallization.

OBSERVATIONS.

THE Pyrites are minerals which by their weight and ſhining colours frequently impoſe on ſuch as are not well acquainted with ores. At firſt ſight they may be taken for very rich ones; and yet they conſiſt only of a ſmall quantity of metal combined with much ſulphur or arſenic, and ſometimes with both.

They ſtrike fire with a ſteel as flints do, and emit a ſulphureous ſmell: ſo that they may be known by this extemporaneous proof. The metal moſt commonly and moſt abundantly found in the Pyrites is iron; the quantity whereof ſometimes equals, or even exceeds, that of the ſulphur. Beſides metallic and ſulphureous matters, the Pyrites contain alſo ſome unmetallic earth.

There are ſeveral ſorts of Pyrites: ſome of them contain only iron and arſenic: they have not all the property of efflореſcing ſpontaneouſly in the air,

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and turning into vitriol: none do ſo but ſuch as conſiſt only of iron and ſulphur, or at leaſt contain but a very ſmall portion of copper or of arſenic: and even amongſt thoſe that are compoſed of iron and ſulphur alone, there are ſome that will continue for years together expoſed to the air without ſhooting, and indeed without ſuffering the leaſt ſenſible alteration.

The efforeſcence of the iron Pyrites, and the changes they undergo, are phenomena well worth our notice. They depend on the ſingular property which iron poſſeſſes of decompoſing ſulphur by the help of moiſture. If very fine iron-filings be accurately mingled with flowers of ſulphur, this mixture, being moiſtened with water, grows very hot, ſwells up, emits ſulphureous vapours, and even takes fire: what remains is found converted into Vitriol of Mars. On this occaſion, therefore, the ſulphur is decompoſed; its inflammable part is diſſipated or conſumed; its acid combines with the iron, and a Vitriol ariſes from that conjunction.

This is the very caſe with the Pyrites that conſiſt only of iron and ſulphur; yet ſome of them, as we ſaid before, do not effloreſce ſpontaneouſly and turn to Vitriol. The reaſon probably is, that in ſuch minerals the particles of iron and ſulphur are not intimately mixed together, but ſeparated by ſome earthy particles.

In order to procure Vitriol from Pyrites of this kind, they muſt be for ſome time expoſed to the action of fire, which by conſuming part of their ſulphur, and rendering their texture leſs compact, makes way for the air and moiſture, to which they muſt be afterwards expoſed, to penetrate their ſubſtance, and produce in them thoſe changes with which thoſe others are affected that germinate ſpontaneouſly.

The Pyrites which contain copper and arſenic, and for that reaſon do not effloreſce, muſt likewiſe undergo the action of fire; which, beſides the effects it produces on Pyrites that conſiſt of iron and ſulphur only, diſſipates alſo the greateſt part of the arſenic. Theſe Pyrites being firſt roaſted, and then expoſed to the air for a year or two, do alſo yield Vitriol; but then it is not a pure Vitriol of Iron, but is combined with a portion of blue Vitriol, the baſis of which is Copper.

Sometimes alſo there is Alum in the vitriolic waters drawn off the Pyrites. It was on account of this mixture of different ſalts that we recommended the keeping apart the cryſtals obtained from each different cryſtallization: for by this means they may be examined ſeparately, and the ſpecies to which they belong diſcovered.

When Vitriol of iron is adulterated with a mixture of the Vitriol of copper only, it is eaſy to purify it and bring it to be entirely martial, by diſſolving it in water, and ſetting plates of iron in the ſolution: for iron having a greater affinity than copper with the vitriolic acid, ſeparates the latter from it, and aſſuming its place produces a pure Vitriol of Mars.

In large works for extracting Vitriol from the Pyrites they proceed thus. They collect a great quantity of Pyrites on a piece of ground expoſed to the air, and pile them up in heaps of about three foot high. There they leave them expoſed to the action of the air, ſun, and rain, for three years together; taking care to turn them every ſix months, in order to facilitate the effloreſcence of thoſe which at firſt lay undermoſt. The rain-water which has waſhed thoſe Pyrites is conveyed by proper channels into a ciſtern; and when a ſufficient quantity thereof is gathered, they evaporate it to a pellicle in large leaden boilers, having firſt put into it a quantity of iron, ſome part of which is diſſolved by the liquor, becauſe it contains a vitriolic acid that is not fully ſaturated therewith. When it is ſufficiently evaporated, they draw it off into large leaden or wooden coolers, and there leave it to ſhoot into cryſtals. In theſe laſt veſſels ſeveral ſticks are placed, croſſing each other in all manner of directions, in order to multiply the ſurfaces on which the cryſtals may faſten.

The Pyrites are not the only minerals from which Vitriol may be procured. All the ores of iron and copper that contain ſulphur may alſo be made to yield green or blue Vitriol, according to the nature of each, by torrefying them, and leaving them long expoſed to the air: but this uſe is ſeldom made of them, as there is more profit to be got by extracting the metals they contain. Beſides, it is eaſier to obtain Vitriol from the Pyrites than from thoſe other mineral ſubſtances.

PROCESS II.

To extract Sulphur from the Pyrites, and other ſulphureous Minerals.

REDUCE to a coarſe powder any quantity of yellow Pyrites, or other Mineral containing Sulphur. Put this powder into an earthen or glaſs retort, having a long wide neck, and ſo large a body that the matter may fill but two thirds of it. Set the retort in a ſand-bath fixed over a reverberating furnace: fit to it a receiver half full of water, and ſo placed that the noſe of the retort may be about an inch under the water: give a gradual fire, taking care you do not make it ſo ſtrong as to melt the matter. Keep the retort moderately red for one hour, or an hour and half, and then let the veſſels cool.

Almoſt all the Sulphur ſeparated by this operation from its matrix will be found at the extremity of the neck of the retort, being fixed there by the water. You may get it out either by melting it with ſuch a gentle heat as will not ſet it on fire, or by breaking the neck of the retort.

OBSERVATIONS.

OF all minerals the Pyrites contain the moſt Sulphur; thoſe eſpecially which have the colour of fine braſs, a regular form, ſuch as round, cubical, hexagonal, and being broken preſent a number of ſhining needles, all radiating, as it were, from a center.

A very moderate heat is ſufficient to ſeparate the Sulphur they contain. We directed that the retort employed ſhould have a long and a wide neck, with a view to procure a free paſſage for the Sulphur: the water ſet in the receiver detains the Sulphur, fixes it, and prevents it from flying off; ſo that it is unneceſſary to cloſe the joints of the veſſels. But it is proper to take notice that when ever you uſe an apparatus for diſtilling, which requires the beak of the retort to be under water, it is of very great conſequence that the fire be conſtantly ſo regulated that the retort may not cool in the leaſt: for in that caſe, as the rarefied air contained therein would be condenſed, the water in the receiver would riſe into the retort and break it.

If in diſtilling Sulphur according to the preſent proceſs the matter contained in the retort ſhould happen to melt, the operation would be thereby conſiderably protracted, and it would require a great deal more time to extract all the Sulphur; becauſe all evaporation is from the ſurface only, and the matter, while it remains in a coarſe powder, preſents a much more extenſive ſurface than when it is melted.

This remark holds with regard to all other diſtillations. Any quantity of liquor, ſet to diſtil in its fluid ſtate, will take much more time to riſe in vapours, and paſs from the retort into the receiver,

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than if it be incorporated with ſome ſolid body reduced to minute parts, ſo that the whole ſhall make a moiſt powder ; and this though the very ſame degree of fire be applied in both caſes.

If the matter from which it is propoſed to extract Sulphur be ſuch as will melt with the degree of fire neceſſary to this operation ; that is, with a heat which will make the retort but faintly red, it muſt be mixed with ſome ſubſtance that is not ſo fuſible. Very pure coarſe ſand or clean gravel may be uſed with ſucceſs : but abſorbent earths are altogether improper for this purpoſe, becauſe they will unite with the Sulphur.

The ſulphureous minerals which are moſt apt to fuſe are the cupreous Pyrites, or yellow copper ores : common lead ores are alſo very fuſible.

The Pyrites are by this operation deprived of almoſt all the Sulphur they contain ; and conſequently little is left behind, but the particles of iron and copper, together with a portion of unmetallic earth, which we ſhall ſhew how to ſeparate from theſe metals when we come to treat of them. I ſay that by this operation the Pyrites are deprived of almoſt all, and not entirely of all their Sulphur ; becauſe, this ſeparation being made in cloſe veſſels only, there always remains a certain quantity of Sulphur, which adheres ſo obſtinately to the metals, that it would be almoſt impoſſible to get it all out, even though a much ſtronger fire than that directed in the proceſs were applied for this purpoſe, and though choice had been, as it ought to be, made of ſuch Pyrites, or other ſulphureous Minerals, as part moſt eaſily with their Sulphur. Nothing but a very ſtrong fire in the open air is capable of carrying it wholly off, or conſuming it entirely.

In ſeveral places are found great quantities of native Sulphur. The Volcanos abound with it, and people gather it at the foot of thoſe burning mountains.

tains. Several ſprings of mineral waters alſo yield Sulphur, and it is ſometimes found ſublimed to the vaulted roofs of certain wells, and among others in one at Aix-la-Chapelle.

The Germans and Italians have large works for extracting Sulphur in quantities out of Pyrites, and other minerals which abound therewith. The proceſs they work by is the ſame with that here delivered; with this difference only, that Sulphur being but of ſmall value they do not uſe ſo many precautions. They content themſelves with putting the ſulphureous minerals into large crucibles, or rather earthen cucurbits, which they place in the furnace in ſuch a manner that, when the ſulphureous part melts, it runs into veſſels filled with water, and is thereby fixed.

The Sulphur obtained, either by diſtillation or by ſimple fuſion, is not always pure.

When it is obtained by diſtillation, if the matters from which you extract it contain moreover ſome other minerals of nearly the ſame volatility, ſuch, for inſtance, as Arſenic, or Mercury, theſe minerals will come over with it. This is eaſily perceived; for pure ſublimed Sulphur is always of a beautiful yellow, inclining to a lemon colour. If it look red, or have a reddiſh caſt, it is a ſign that ſome Arſenic hath riſen along with it.

Mercury ſublimed with Sulphur likewiſe gives it a red colour; but Sulphur is very ſeldom adulterated with this metallic ſubſtance: for Arſenic is frequently found combined with the Pyrites and other ſulphureous minerals, whereas on the contrary we very rarely meet with any Mercury in them.

But if Mercury ſhould happen to riſe with the Sulphur in diſtillation, it may be diſcovered by examining the ſublimate; which, in that caſe, will have the properties of Cinabar: on being broken its inſide will appear to conſiſt of needles adhering laterally to each other; its weight will be very conſiderable; and laſtly, the great heat of the place where it is collected will furniſh another mark to know it by; for as Cinabar is leſs volatile than Arſenic or Sulphur, it faſtens on places too hot for either Sulphur or Arſenic to bear.

Sulphur may alſo be adulterated with ſuch fixed matters, either metallic or earthy, as it may have carried up along with it in the diſtillation, or as may have been ſublimed by the Arſenic, which has a ſtill greater power than Sulphur to volatilize fixed bodies.

If you deſire to free the Sulphur from moſt of theſe heterogeneous matters, it muſt be put into an earthen cucurbit, and ſet in a ſand bath. To the cucurbit muſt be fitted one or more aludels, and ſuch a degree of heat applied as ſhall but juſt melt the Sulphur; which is much leſs than that neceſſary to ſeparate the Sulphur from its matrix. As ſoon as the Sulphur is melted it will ſublime in lemon-coloured flowers, that will ſtick to the inſides of the aludels.

When nothing more appears to riſe with this degree of heat, the veſſels muſt be ſuffered to cool. At the bottom of the cucurbit will be found a ſulphureous maſs, containing the greateſt part of the adventitious matters that were mixed with the Sulphur, and more or leſs red or dark-coloured according to the nature of thoſe matters.

When we come to treat of Arſenic and Mercury we ſhall give the methods of ſeparating Sulphur entirely from thoſe metallic ſubſtances.

PROCESS III.

To extract Alum from aluminous Minerals.

TAKE ſuch minerals as are known or ſuſpected to contain Alum. Expoſe them to the air, that they may effloreſce. If they remain there a year without any ſenſible change, calcine them, and then leave them expoſed to the air, till a bit thereof being put on the tongue imparts an aſtringent aluminous taſte.

When your matters are thus prepared, put them into a leaden or glaſs veſſel; pour upon them thrice their weight of hot water; boil the liquor; filter it; and repeat theſe operations till the earth be ſo edulcorated that the water which comes off it hath no taſte. Mix all theſe ſolutions together, and let them ſtand four and twenty hours, that the groſs and earthy parts may ſettle to the bottom; or elſe filter the liquor; then evaporate till it will bear a new-laid egg. Now let it cool, and ſtand quiet four and twenty hours: in that time ſome cryſtals will ſhoot, which are moſt commonly vitriolic; for Alum is rarely obtained by the firſt cryſtallization. Remove theſe vitriolic cryſtals: if any cryſtals of Alum be found amongſt them, theſe muſt be diſſolved anew, and ſet to cryſtallize a ſecond time in order to their purification; becauſe they partake of the nature as well as of the colour of vitriol. By this method extract all the Alum that the liquor will yield.

If you get no cryſtals of Alum by this means, boil your liquor again, and add to it a twentieth part of its weight of a ſtrong alkaline lixivium, or a third part of its weight of putrefied urine, or a ſmall quantity of quick-lime. Experience and repeated trials muſt teach you which of theſe three ſubſtances is to be preferred, according to the particular nature of the mineral on which you are to operate. Keep your liquor boiling, and if there be any Alum in it, there will appear a white precipitate: in that caſe let it cool and ſettle. When the white precipitate is entirely fallen, decant the clear, and leave the cryſtals of Alum to ſhoot at leiſure, till the liquor will yield no more: it will then be exceeding thick.

OBSERVATIONS.

ALUM is obtained from ſeveral ſorts of Minerals. In ſome parts of Italy, and in ſundry other places, it effloreſces naturally on the ſurface of the earth. There it is ſwept together with brooms, and thrown into pits full of water. This water is impregnated therewith till it can diſſolve no more. Then it is filtered, and ſet to evaporate in large leaden veſſels; and when it is ſufficiently evaporated, and ready to ſhoot into cryſtals, it is drawn off into wooden coolers, and there left for the ſalt to cryſtallize.

In aluminous ſoils there are often found ſprings ſtrongly impregnated with Alum; ſo that to obtain it the water need only be evaporated.

In the country about Rome there is a very hard ſtone, which is hewn out of the quarry juſt like other ſtones for building: this ſtone yields a great deal of Alum. In order to extract it, the ſtones are calcined for twelve or fourteen hours; after which they are expoſed to the air in heaps, and carefully watered three or four times a day for forty days together. In that time they begin to effloreſce, and to throw out a reddiſh matter on their ſurface. Then they are boiled in water, which diſſolves all the Alum they contain, and being duly evaporated gives it back in cryſtals. This is the Alum called *Roman Alum*.

Several ſorts of Pyrites alſo yield a great deal of Alum. The Engliſh have a ſtone of this kind, which in colour is very like a ſlate. This ſtone contains much Sulphur, which they get rid of by roaſting it. After this they ſteep the calcined ſtone in water, which diſſolves the Alum it contains, and to this ſolution they add a certain quantity of a lye made of the aſhes of ſea-weeds.

The Swedes have a Pyrites of a bright, golden colour, variegated with ſilver ſpots, from which they procure Sulphur, Vitriol, and Alum. They ſeparate from it the Sulphur and the Vitriol by the methods above preſcribed. When the liquor which hath yielded Vitriol is become thick, and no more vitriolic cryſtals ſhoot in it, they add an eighth part of its weight of putrefied urine, mixed with a lye made of the aſhes of green wood. Upon this there appears and falls to the bottom a copious red ſediment. They decant the liquor from this precipitate, and when it is duly evaporated find it ſhoot into beautiful cryſtals of Alum.

What hath been ſaid, concerning the ſeveral matrices from which Alum is obtained, ſufficiently ſhews that it is ſeldom ſolitary in the waters with which aluminous ſubjects have been lixiviated. It is almoſt always accompanied with a certain quantity of Vitriol, or other ſaline mineral matters, which obſtruct its cryſtallization, and prevent its being pure. 'Tis with a view to free it from theſe matters that the waters impregnated with Alum are mixed with a certain quantity of the lye of ſome fixed Alkali, or with putrefied urine, which contains much volatile Alkali. Theſe Alkalis have the property of decompounding all the Neutral ſalts which have for their baſis either an abſorbent earth or a metallic ſubſtance ; and ſuch as have a metallic ſubſtance for their baſis more readily than thoſe whoſe baſis is an earth. Conſequently, if they are mixed with a liquor in which both theſe ſorts of ſalts are diſſolved, they muſt decompound that ſort whoſe baſis is metallic ſooner than the other whoſe baſis is an earth. This is what comes to paſs in a ſolution of Alum and Vitriol. The metallic part of the latter is ſeparated from its acid by the Alkalis when mixed with that ſolution ; and 'tis this metallic part, which is generally iron, that appears in the form of a reddiſh precipitate, as above-mentioned.

But becauſe Alkalis decompound alſo thoſe Neutral ſalts which have an earth for their baſis, care muſt be taken that too much thereof be not added; elſe what you put in, more than is neceſſary to decompound the vitriolic ſalts in your liquor, will attack the Alum, and decompound it likewiſe.

The Alkali made uſe of to promote the cryſtallization of the Alum joins with the Vitriolic Acid which had diſſolved the ſubſtances now precipitated by it, and therewith forms different Neutral ſalts according to its particular nature. If the Alkali be a lixivium of common wood-aſhes, the Neutral ſalt will be a vitriolated Tartar; if a lixivium of the aſhes of a maritime plant like Soda, the Neutral ſalt will be a Glauber's ſalt; if putrefied urine, the Neutral ſalt will be a vitriolic Ammoniacal ſalt. Some of theſe ſalts incorporate with the Alum, which in large works cryſtallizes in vaſt lumps: and hence it comes that ſome ſorts of Alum when mixed with a fixed Alkali ſmell like a volatile Alkali.

The cryſtals of Alum are octaedral, that is, they are ſolids with eight ſides. Theſe octaedral ſolids are triangular pyramids, having their angles cut away, ſo that four of their ſurfaces are hexagons, and the other four triangles.

Sulphur, Vitriol, and Alum are the three principal ſubjects in which we certainly know that the univerſal or Vitriolic Acid particularly reſides, and from which we extract it when we want to have it pure. For this reaſon we thought it proper, before we treated of the extraction of this Acid, to ſhew the method of ſeparating thoſe matters themſelves from the other minerals out of which we obtain them.

Moreover, all the other matrices, in which the Vitriolic Acid is moſt commonly lodged, may be referred to one or other of the matters which ſerve as baſes to theſe three minerals.

To Sulphur we may refer all combinations of the Vitriolic Acid with an inflammable matter: but we muſt take care not to confound Sulphur with thoſe Bitumens in which the Vitriolic Acid may be found: for the baſis of thoſe bitumens is a real Oil; whereas the baſis of Sulphur is the pure Phlogiſton. Yet as Oils themſelves contain the Phlogiſton, which in union with the Vitriolic Acid forms a true Sulphur, it follows that ſuch bitumens may in a certain reſpect be claſſed with Sulphur.

The ſame is to be ſaid of Vitriol. The name is uſually given to ſuch combinations only as are formed of the Vitriolic Acid with Iron or Copper, which make the green and blue Vitriol; and to a third ſpecies of Vitriol, which is white, and has Zinc for its baſis: but as the Vitriolic Acid may, by particular combinations, be united with many other metallic ſubſtances, all ſuch Metallic Salts muſt be referred to the claſs of Vitriols.

The ſame may alſo be ſaid of Alum, which is no other than a combination of the Vitriolic Acid with a particular kind of abſorbent earth; ſo that all combinations of this Acid with any earth whatever may be placed in the ſame claſs.

This laſt claſs of mixts is the moſt extenſive of all that contain the Vitriolic Acid; becauſe there are a vaſt many earths, all differing from one another, with which that Acid may be united. Alum properly ſo called, the Gypſums, Talcs, Selenites, Boles, and all the other compounds of this kind, differ from each other only in their particular earths.

The different properties of theſe earthy ſalts depend on the nature of their baſes. Thoſe which are of the aluminous kind retain much water in cryſtallizing, which makes them very ſoluble in water, and gives them the property of acquiring readily the aqueous fluor when expoſed to the fire. Thoſe which are of the nature of the Selenites admit but very little water in their cryſtals, and conſequently are almoſt inſoluble in water; nor does the fire give them an aqueous fluor. Laſtly, the Gypſums and

Talc

Talcs are ſtill more deſtitute of theſe properties. The natures of the earths in theſe ſeveral compounds are hitherto but very imperfectly known, and may give the Chymiſts occaſion for enquiries equally curious and uſeful.

The Vitriolic Acid is ſometimes found complicated with a fixed alkaline baſis. This is almoſt always the Alkali of Sea-ſalt; ſo that the compound is a Glauber's Salt. Some mineral waters are impregnated therewith; which happens when theſe waters contain Vitriol or Alum, together with Sea-ſalt.

From the principles laid down, in our Elements of the Theory, it appears that the Vitriolic Acid hath not ſo great an affinity with earthy and metallic ſubſtances as with fixed Alkalis; and alſo that it is ſtronger than the Marine Acid, and hath a greater affinity with fixed Alkalis. This being allowed, the generation of native Glauber's Salts is eaſily accounted for. The Acid of aluminous or Vitriolic ſalts quits the earth or the metal with which it was combined, and expelling the Acid of Sea-ſalt unites with its baſis. Warmth greatly promotes theſe decompoſitions.

If the common foſſil ſalt, uſually called *Sal Gem*, or any other kind of Sea-ſalt, ſhould happen to be near a Vulcano when it diſcharges flaming Sulphur, as is frequently the caſe, and if this Sulphur ſhould run among the Sea-ſalt, a Glauber's Salt would inſtantly be formed in that place; becauſe when Sulphur burns its Acid is ſeparated and ſet at liberty.

Laſtly, if aluminous or vitriolic matters, or burning Sulphur, ſhould meet with the aſhes of plants or trees conſumed by fire, a vitriolated Tartar would be formed; becauſe theſe aſhes contain a fixed Alkali of the ſame nature with that of Tartar.

The Vitriolic Acid when combined with an earthy baſis adheres ſtrongly thereto; ſo that the force of fire is able to expell very little or none of it. There is no way of ſeparating it from ſuch a baſis, but by preſenting to it an Alkaline Salt, with which it will unite: nor is it ever extracted from ſuch matters when it is required pure. It does not adhere ſo firmly to metallic ſubſtances; but is ſeparated from them by the force of fire: ſo that it may be obtained from the ſeveral ſorts of Vitriol. It is uſually drawn from Green Vitriol; that being the commoneſt ſort.

As to Sulphur, the Phlogiſton which is its baſis being the ſubſtance wherewith the Vitriolic Acid hath the greateſt affinity, it would be altogether impoſſible to decompoſe it, and to ſeparate its Acid, if it were not inflammable; but by burning it the Phlogiſton is deſtroyed, and leaves the Acid at liberty. By this means therefore it may be ſeparated. We ſhall now give the Proceſſes for extracting the Acid from Vitriol and Sulphur.

PROCESS IV.

To extract the Vitriolic Acid from Green Vitriol.

TAKE any quantity of Green Vitriol: put it in an unglazed earthen veſſel, and heat it gradually. Vapours will ſoon begin to riſe. Encreaſe the fire a little, and it will liquefy by means of the water contained in it, and acquire what we called an *aqueous* fluor. Continue the calcination, and it will become leſs and leſs fluid, grow thick, and turn of a greyiſh colour. Now raiſe your fire, and keep it up till the ſalt recover its ſolidity, acquire an orange colour, and begin to grow red where it immediately touches the ſides of the veſſel. Then take it out, and reduce it to powder.

Put the Vitriol thus calcined and pulverized into a good earthen retort, of which one half at leaſt muſt remain empty. Set the retort in a reverberatory furnace: fit thereto a large glaſs receiver, and, having luted the joint well, give fire by degrees. You will ſoon ſee white clouds riſe into the receiver, which will render it opaque and heat it. Continue the ſame degree of fire till theſe clouds diſappear: they will be ſucceeded by a liquor which will trickle down the ſides of the receiver in veins. Still keep up the fire to the ſame degree as long as theſe veins appear. When they begin to abate, encreaſe the fire, and puſh it to the utmoſt extremity: upon this there will come over a black, thick liquor: it will even be found congealed, and prove the Icy Oil of Vitriol, if care hath been taken to change the receiver, keep the veſſels perfectly cloſe, and give a ſufficient degree of heat. Proceed thus till nothing more comes over, or at leaſt very little. Let the veſſels cool, unlute them, pour the contents of the receiver into a bottle, and ſeal it hermetically.

OBSERVATIONS.

GREEN Vitriol retains much water in cryſtallizing; and in order to free it from that ſuperfluous phlegm, it muſt be calcined before you diſtill it. Without this precaution the operation will be exceedingly protracted, and a great deal of time waſted in diſtilling ſuch a quantity of water; which will moreover greatly weaken the Acid by commixing with it, unleſs care be taken to change the recipient as ſoon as the water is all come over.

But there is alſo another advantage in calcining the Vitriol before you put it into the retort: for otherwiſe this ſalt would melt on the firſt application of heat, and run into a maſs; which would prove a great hindrance to its diſtillation. This inconvenience is avoided by a previous calcination, in conſequence whereof the Vitriol is eaſily reduced to a powder which never becomes fluid.

Vitriol calcined as directed in the proceſs grows ſo hard, and adheres ſo firmly to the veſſel in which the calcination is performed, that it requires no ſmall pains to ſeparate and pulverize it. Care muſt be taken to put it into the retort as ſoon as it is pulverized, and to ſtop that veſſel very cloſe if you do not begin the diſtillation immediately: for otherwiſe it will naturally attract from the air almoſt all the moiſture it hath loſt.

The Acid which Vitriol yields by diſtillation is ſulphureous; probably becauſe it ſtill retains ſome of the Phlogiſton, with which it was united when under the form of Sulphur in the Pyrites; or elſe hath laid hold on a portion of that belonging to the iron which ſerved for its baſis in Vitriol. But this ſulphureous part is volatile, and flies off in time.

This decompoſition of Vitriol in cloſe veſſels is a difficult and laborious proceſs. To carry the operation to its utmoſt perfection requires a fire of extreme violence, kept up without intermiſſion during four or five days; ſuch in ſhort as few veſſels are able to bear. Of courſe this operation is ſeldom performed in laboratories. The French Chymiſts fetch their Oil of Vitriol from Holland, where it is extracted from Vitriol in large quantities, by means of furnaces erected for the purpoſe, in which many retorts are employed at once.

In the Memoirs of the Academy of Sciences M. Hellot hath given us the moſt material circumſtances of a very fine experiment of this kind, in which he puſhed the diſtillation of Green Vitriol to the utmoſt. Into a German retort * he put ſix pounds of Green Engliſh Vitriol calcined to redneſs, which he expoſed to a fire of the extremeſt violence, conſtantly kept up during four days and four nights. At the expiration of that time he found in the veſſels em-

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* They are much the beſt, and bear a very fierce heat.

ployed as receivers an Icy Oil of Vitriol, which was altogether in a cryſtalline form and black. The precautions neceſſary to make this experiment ſucceed he repreſents in the following terms.

" The ſucceſs of this operation, which produces " an Oil of Vitriol perfectly Icy and without any " liquor, depends on the care taken to prevent the " acid vapours, driven by the fire out of Vitriol " calcined to redneſs, from having any communi" cation with the external air while they are diſtil" ling: for otherwiſe they will attract from it " a moiſture which will keep them fluid in the re" ceiver. The receiver muſt be at ſuch a diſtance " from the furnace that it may remain cool enough " for the vapours to condenſe in it. There muſt " alſo be ſufficient room for thoſe vapours to circu" late in, and to prevent the ſulphureous exploſions, " which are every now and then diſcharged out of " the retort, from burſting the veſſels: for though " the previous calcination of the Vitriol hath car" ried off the moſt volatile, yet there ſtill remains " enough of the inflammable principle, even in " the iron itſelf, to form a Sulphur with the Acid " as it is extricated, or at leaſt a mixt that would " be as apt to take fire as common Sulphur, if it " were not over-doſed with the Acid.

" As the beſt means of gaining theſe ends M. " Hellot contrived to adapt to the neck of his re" tort a receiver with two necks, the lowermoſt of " which was inſerted into a large ballon. Receivers " applied to each other in this manner are called " Adopters.

" It is no eaſy matter to get this Icy Oil out of " the ballon: for as ſoon as the air touches it ſuch " a thick cloud of ſulphureous fumes ariſes, that " it is abſolutely neceſſary to place the veſſel on " ſome ſhelf over head, becauſe a man cannot ſtand "exposed thereto for a single minute without being "ſuffocated."

This Icy Acid muſt be ſhut up with all poſſible expedition in a cryſtal bottle accurately cloſed with a glaſs ſtopple, which ſhould be rubbed with emery in its neck ſo as to fit it exactly: for it attracts the moiſture of the air ſo powerfully that unleſs exceeding great care be taken to prevent all communication with the external air it will ſoon diſſolve into a fluid.

"The Icy Oil is black; becauſe the acid vapours "carry over with them ſomewhat of a greaſy matter, "from which Vitriol is ſeldom free, and which "always appears, after repeated ſolutions and cryſ"tallizations of this Salt, in the mother-water "which will ſhoot no more. Now the ſmalleſt "portion of inflammable matter preſently blackens "the moſt highly rectified Oil of Vitriol, which is "perfectly clear.

"The Vitriolic Acid, when forced over by a vio"lent heat, carries along with it ſome ferruginous par"ticles alſo, that want nothing but to be united with "a Phlogiſton to become true iron. They are ea"ſily diſcovered, either in the common black Oil "of Vitriol, or in the blackiſh cryſtals of the Icy "Oil, by only diſſolving them in a large quantity "of diſtilled water: for after ſeven or eight days "digeſtion a light powder or downy ſediment preci"pitates, which being calcined in a violent fire is "partly attracted by the magnet; and being again "calcined with bees-wax becomes almoſt entirely "iron."

The *Caput mortuum* of this diſtillation of Vitriol is the ferruginous earth of this Salt, and is called *Colcothar*. When this Colcothar hath undergone a violent fire, as in the experiment now related, ſcarce any Acid remains therein. Out of ſix pounds of Vitriol that M. Hellot uſed, he could recover no more, by lixiviating what was left in the retort,

than

than two ounces of a Vitriolic Salt; and even that was very earthy.

If Vitriol be expoſed to a fire neither ſo violent nor ſo long continued, its Colcothar will yield a greater quantity of Vitriol that hath not been decompoſed. A white cryſtalline ſalt is alſo obtained from it, and called *Salt of Colcothar*; which is no other than the ſmall portion of Alum uſually contained in Vitriol, and not ſo eaſily decompoſed by the action of fire.

PROCESS V.

To decompoſe Sulphur, and extract its Acid, by burning it.

TAKE any quantity of the pureſt Sulphur: fill therewith a crucible or other earthen diſh: heat it till it melts: then ſet it on fire, and when its whole ſurface is lighted place it under a large glaſs head, ſo that the flame of the Sulphur do not touch either its ſides or bottom; that the air have free acceſs, in order to make the Sulphur burn clear; that the head incline a little toward the ſide on which its beak is, that as the vapours condenſe therein the liquor may run off with eaſe. To the beak of this veſſel fit a receiver: the fumes of the lighted Sulphur will be condenſed, and gather into drops in the head, out of which they will run into the receiver. There, when the Sulphur has done burning, you will find an Acid liquor, which is the Spirit of Sulphur.

OBSERVATIONS.

IN the burning of Sulphur, the Phlogiſton which ſerves for its baſis is diſſipated, and ſeparated from the Acid which is left at liberty. The acid fumes which riſe from the lighted ſulphur ſtrike againſt the inſide of the head placed over it, are there condenſed, and appear in the form of a liquor. But as Sulphur, like all other inflammable bodies, Nitre excepted, will not burn in cloſe veſſels, it is neceſſary that the air be freely admitted here; which occaſions the loſs of a great deal of the Acid of the Sulphur, as is evident from the pungent ſuffocating ſmell perceived in the laboratory during the operation.

This Acid, while combined with the Phlogiſton, is incapable of contracting any union with water; but when alone is very apt to mix therewith: it is even proper to put ſome in its way, that it may incorporate therewith as ſoon as it is diſcharged from the Sulphur; for it is then very free from phlegm, very volatile, and conſequently very little diſpoſed to condenſe into a liquor, but on the contrary very apt to fly off in vapours. The water, which it imbibes with a kind of avidity, fixes and detains it; ſo that by this means a much greater quantity thereof is obtained from Sulphur, than if it were diſtilled without this precaution.

It is proper therefore now and then to introduce a diſh full of hot water under the head which receives the fumes of the Sulphur. The vapours that exhale from the water bedew the inſide of the head, and procure the advantage we are ſpeaking of.

The ſame thing may be effected ſeveral other ways: thus, the crucible containing the Sulphur may be ſet on a foot placed in an earthen diſh with ſome water in it; which however muſt not riſe above the foot; for if it ſhould reach the crucible, it might cool and fix the ſulphur. The diſh thus prepared muſt be placed on a ſand-bath hot enough to make the water ſmoke continually; and over all is to be placed the head as directed in the proceſs.

The ſize and form of the veſſel which immediately receives the ſulphureous fumes may alſo contribute to increaſe the quantity of the Acid Spirit. A very large veſſel, with a hole at bottom no wider than is juſt ſufficient to admit the vapours, is the propereſt for this operation.

After the Sulphur has burnt for ſome time, it often happens that a ſort of ſkin or cruſt forms on its ſurface, which is not inflammable, but gradually leſſens the quantity and vigour of the flame as it increaſes in thickneſs, and at laſt puts it quite out. This cruſt proceeds from the impurities, and heterogeneous uninflammable particles contained in the ſulphur. Care muſt be taken to remove it with an iron wire as faſt as it forms.

Two quantities of Sulphur may alſo be kept in two crucibles, and heated alternately. That in which the Sulphur is hot and melted may be ſubſtituted for the other in which the Sulphur is grown cold and fixed; becauſe cold Sulphur does not burn well.

The Spirit of Sulphur is at firſt pungent and volatile, becauſe it ſtill retains a ſmall portion of the Phlogiſton: but that ſulphureous part flies off, eſpecially if the bottle in which the Spirit is kept be left for ſome time unſtopped.

The Acid obtained from Sulphur appears by all chymical proofs perfectly like that obtained from Vitriol: they differ in this only that the former is the pureſt; for the Acid obtained from Vitriol carries over with it ſome metallic parts, as we obſerved before, which can never happen to that obtained from Sulphur.

If linnen rags dipped in a ſolution of Fixed Alkali be expoſed to the fumes of burning brimſtone, the Spirit of Sulphur joins with the Alkali, and therewith forms a Vitriolated Tartar. This Salt is known to be formed when the rags grow ſtiff, and appear ſpangled with a vaſt many glittering points, which are nothing but little cryſtals of the Salt we are ſpeaking of.

When the Sulphur burns very gently and ſlowly the Spirit that exhales from it is ſo much the more ſulphureous and volatile: and hence the Salt formed by the combination of this Spirit with the Alkali expoſed to it in linnen rags, as in the above-mentioned experiment, is not at firſt a Vitriolated Tartar; but a Neutral Salt of a particular kind, which is capable of being decompoſed by any other Mineral Acid, the ſulphureous Acid having leſs affinity than any of the reſt with Alkalis. Nevertheleſs this Salt becomes in time a true Vitriolated Tartar, becauſe the ſulphureous part which weakened its Acid eaſily quits it and flies off.

PROCESS VI.

To concentrate the Vitriolic Acid.

TAKE the Vitriolic Acid you intend to concentrate, that is, to dephlegmate and make ſtronger: pour it into a good glaſs retort, of ſuch a ſize that your quantity of Acid may but half fill it; ſet this retort in the ſand-bath of a reverberating furnace: fit to it a receiver: lute it on, and give a gradual fire. There will come over into the receiver a clear liquor, the firſt drops of which will be but faintly Acid: this is the moſt aqueous part.

When the drops begin to follow one another much more ſlowly, raiſe your fire, till the liquor begin to bubble a little in the middle. Keep it thus gently boiling, till one half or two thirds thereof be come over into the receiver. Then let your veſſels cool; unlute them; what remains in the retort pour into a cryſtal bottle, and ſtop it exactly with a glaſs ſtopple rubbed with emery.

OBSERVATIONS.

THE Acid obtained from Sulphur is generally very aqueous; either becauſe in preparing it water muſt neceſſarily be adminiſtered, that it may unite therewith as it ſeparates from the Sulphur; or becauſe it is ſo greedy of moiſture as to attract a great deal from the air, which muſt needs be admitted to make the Sulphur burn.

The Acid obtained from Vitriol, excepting that which riſes laſt, is alſo mixed with a pretty conſiderable quantity of phlegm; becauſe the Vitriol, though calcined, ſtill retains a great deal thereof, which riſes with the Acid in diſtillation. Now, as there are many chymical experiments that will not ſucceed without Acids exceedingly dephlegmated, it is proper to have in a laboratory all the Acids thus conditioned; becauſe, if they happen to be too ſtrong for particular operations, as is ſometimes the caſe, it is very eaſy to lower them to the deſired degree, by adding a ſufficient quantity of water.

The Vitriolic Acid is much heavier and much leſs volatile than water. If therefore a mixture of theſe two liquors be expoſed to the fire, the aqueous part will riſe with a degree of heat which is not able to carry up the Acid: by this means they may be ſeparated from each other; and thus is the Vitriolic Acid concentrated.

Nevertheleſs, as this Acid combines moſt cloſely with water, and is in a manner ſtrongly connected with it, the water carries up ſome portion thereof along with it; and hences it comes that the liquor which riſes into the receiver is Acid: it is called *Spirit of Vitriol.*

As the fire carries off the moſt aqueous part, the other which remains in the retort increaſes in ſpecific gravity. The Acid particles are brought nearer together, retain the aqueous particles more obſtinately, and therefore to ſeparate them the degree of heat muſt be increaſed.

It is uſual to draw off one half or two thirds of the liquor that was put into the retort: but this depends on the degree of ſtrength the Acid was of before concentration, and the degree of concentration intended to be given it.

If the Acid to be concentrated be Oil of Vitriol, from being brown or black it grows clearer as the operation advances, and at laſt becomes perfectly colourleſs and tranſparent; becauſe the fat matter, which tinged it black, is diſſipated during the proceſs. Some of it depoſites a white cryſtalline earth.

A ſulphureous ſmell is generally perceived about the veſſels in this operation. This ariſes from a ſmall portion of the Phlogiſton from which the Acid is not free; and 'tis this inflammable matter which gives the Oil of Vitriol its black colour: for the cleareſt and beſt rectified Oil of Vitriol will become brown, and even black, in a ſhort time, if any inflammable matter, though in a very ſmall quantity, be diſſolved therein.

The veſſels are luted in this operation, to prevent any loſs of the Spirit of Vitriol, which being very acid is of uſe in many chymical experiments, and may itſelf alſo be again concentrated.

We obſerved that in this operation it is neceſſary the retort ſhould be of very good glaſs. Indeed the Acid is ſo active and ſo ſtrong, that, if the glaſs be tender and have a little too much ſalt in its compoſition, it will be ſo corroded thereby that it will fall to pieces.

Though we directed the retort to be ſet in a ſand-bath for this operation, it does not follow that it may not alſo be placed in a naked fire: on the contrary, when the heat is not conveyed through a bath the operation advances faſter, and is much leſs tedious. But then great caution muſt be uſed, and the cloſeſt attention given to the management of the fire, which muſt be raiſed by almoſt imperceptible degrees, eſpecially at the beginning of the operation; otherwiſe it is next to a certainty that the veſſels will break. In general, a naked fire may be employed in almoſt all diſtillations which require a greater degree of heat than that of boiling water, or the *balneum mariæ*: the operation will be ſooner finiſhed; but it requires an experienced hand, that has by practice acquired a habit of governing the fire with judgment.

There is moreover another advantage in not uſing the ſand-bath; which is, that if in the time of the operation you perceive the fire too fierce, you can quickly check it, either by ſtopping cloſe all the apertures of the furnace, or by drawing out all or part of the lighted coals. This inconvenience is not near ſo eaſily remedied when you uſe the ſand-bath; becauſe when once heated, it retains its heat very long after the fire is quite extinguiſhed.

PROCESS VII.

To decompoſe Vitriolated Tartar by means of the Phlogiſton; or to compoſe Sulphur by combining the Vitriolic Acid with the Phlogiſton.

TAKE equal parts of Vitriolated Tartar, and very dry Salt of Tartar, ſeparately reduced to powder; add an eighth part of their weight of charcoal-duſt; and mix the whole together very accurately. Throw this mixture into a red hot crucible, placed in a furnace filled with burning coals. Cover it very cloſe, and keep it very hot, till the mixture melt, which may be known by uncovering the crucible from time to time. There will then appear a blueiſh flame, accompanied with a pungent ſmell of Sulphur.

Take the crucible out of the fire: diſſolve its contents in hot water: filter the ſolution through brown paper ſupported by a glaſs funnel: drop into the filtered liquor by little and little any Acid whatever. As you add the Acid the liquor will grow more and more turbid, and let fall a grey precipitate. Continue dropping in more Acid till the liquor will yield no more precipitate. Filter it a ſecond time, to ſeparate it from the precipitate: what remains on the filter is a true inflammable Sulphur, which you may either melt or ſublime into flowers.

OBSERVATIONS.

ALL bodies that contain the Vitriolic Acid may contribute, as well as Vitriolated Tartar, to the generation of Sulphur: ſo that all the neutral Salts in which this Acid is a principle, the Alums, Selenites, Gypſums, Vitriols, may be ſubſtituted for it in this experiment. All theſe matters, with the addition of charcoal-duſt only, being fuſed in a crucible, conſtantly produce Sulphur; becauſe the Vitriolic Acid having a greater affinity with the Phlogiſton than with any thing elſe, will quit its baſis, whatever it be, to join with the Phlogiſton of the charcoal, and therewith form a Sulphur.

The fixed Alkali added thereto helps to promote the fuſion of the ingredients, which is neceſſary for effecting the deſired combination. It alſo ſerves to unite with the Sulphur, when formed; and thus makes the combination called *Liver of Sulphur*, which prevents the Sulphur from being conſumed as ſoon as formed: for the fixed Alkalis, which are incombuſtible, hinder Sulphur from burning ſo eaſily as it would do if they were not joined with it. They may afterwards be ſeparated from each other, by the means of any Acid whatever.

This proceſs, in which Sulphur is regenerated, by re-combining together the principles of which it was originally compoſed, is one of the moſt beautiful experiments that modern Chymiſtry hath produced. We are indebted for it to M. Stahl; and Doctor Geoffroy hath given a particular account of it in the Memoirs of the Academy of Sciences.

Before theſe gentlemen Glauber and Boyle had indeed publiſhed methods of producing Sulphur. Glauber made uſe of his *Sal mirabile* and powdered charcoal: Boyle employed the Vitriolic Acid and Oil of Turpentine. But neither of thoſe Chymiſts underſtood the true theory of their operations: they did not thoroughly know the principles of Sulphur: they did not imagine they had compoſed Sulphur; they thought they only extracted what they ſuppoſed to exiſt previouſly in the matters they employed in their experiments.

M. Stahl was the firſt who diſcovered and explained the nature of Sulphur, and proved that in Glauber's and Boyle's experiments Sulphur was actually produced, by uniting together the principles of which it is conſtituted. This beautiful experiment gives the ſtrongeſt luſtre of evidence to the theory of the compoſition of that mixt, which acts ſuch a capital part in Chymiſtry; and it can no longer be doubted that Sulphur is actually a combination of the Vitriolic Acid with the Phlogiſton.

Beſides this important truth, our proceſs for compoſing Sulphur by art proves ſeveral others that are equally eſſential and fundamental.

The firſt is that the Vitriolic Acid hath a greater affinity with the Phlogiſton than with any other thing, ſeeing it quits metallic and earthy ſubſtances, as well as Alkaline ſalts, in order to combine therewith.

The ſecond is that Sulphur combines with fixed Alkalis without ſuffering any decompoſition; ſeeing it may be ſeparated from them entire and unaltered; and ſeeing that very Sulphur, which is naturally indiſſoluble in water, is rendered ſoluble therein by the union it hath contracted with the fixed Alkali.

The third is that the Vitriolic Acid, which when it is pure hath the greateſt affinity with Alkalis of any Acid whatever, loſes a great deal of that affinity by contracting an union with the Phlogiſton; ſeeing the weakeſt Acids are capable of decompoſing the Liver of Sulphur, and ſeparating the Sulphur from the Alkali. And this alſo confirms one of the general propoſitions concerning affinities advanced in our theory; to wit, that the affinities of compound or mixed ſubſtances are weaker than thoſe of the ſame ſubſtances in a purer or more ſimple ſtate.

CHAP. II.

Of the NITROUS ACID.

PROCESS I.

To extract Nitre out of nitrous Earths and Stones. The Purification of Salt Petre. Mother of Nitre. Magneſia.

TAKE any quantity of nitrous earths or ſtones; reduce them to powder; and therewith mix a third part of the aſhes of green-wood and quicklime. Put this mixture into a barrel or vat, and pour on it hot water to about twice the weight of the whole maſs. Let it ſtand thus for twenty four hours, ſtirring it from time to time with a ſtick. Then filter the liquor through brown paper, or paſs it through a flannel bag, till it come clear: it will then have a yellowiſh colour. Boil this liquor, and evaporate till you perceive that a drop of it let fall on any cold body coagulates. Then ſtop the evaporation, and ſet your liquor in a cool place. In the ſpace of four and twenty hours cryſtals will be formed in it, the figure of which is that of an hexagonal priſm, having its oppoſite planes generally equal, and terminated at each extremity by a pyramid of the ſame number of ſides. Theſe cryſtals will be of a browniſh colour, and deflagrate on a live coal.

Decant the liquor from theſe cryſtals; mix it with twice its weight of hot water; evaporate and cryſtallize as before. Repeat the ſame operation till the liquor will yield no more cryſtals: it will then be very thick, and goes by the name of *Mother of Nitre.*

OBSERVATIONS.

EARTHS and ſtones that have been impregnated with animal or vegetable juices ſuſceptible of putrefaction, and have been long expoſed to the air, but ſheltered from the ſun and rain, are thoſe which yield the greateſt quantity of Nitre. But all ſorts of earths and ſtones are not equally fit to produce it. None is ever found in flints or ſands of a cryſtalline nature.

Some earths and ſtones abound ſo with Nitre, that it effloreſces ſpontaneouſly on their ſurface, in the form of a cryſtalline down. This Nitre may be collected with brooms, and accordingly has the name of *Salt-Petre Sweepings*. Some of this ſort is brought from India.

Hitherto we are much in the dark as to the origin and generation of Nitre. Some Chymiſts pretend that the Nitrous Acid is diffuſed through the air, and gradually depoſited in ſuch earths and ſtones as are qualified to receive it.

Others, conſidering that none of it is ever obtained but from earths that have been impregnated with vegetable or animal juices, have from thence concluded thoſe two kingdoms to be the general repoſitories of the Nitrous Acid; that if we do not perceive it to exiſt in ſuch matters at all, or at leaſt in any great quantity, till they have undergone putrefaction, and are in ſome meaſure incorporated with ſuitable earths and ſtones, 'tis becauſe the Acid is ſo entangled with heterogeneous particles that it requires the aſſiſtance of putrefaction, and much more of filtration through an earth, to diſengage it, and enable it to appear in its proper nature.

Laſtly, others are of opinion that this Acid is no other than the univerſal or Vitriolic Acid; diſguiſed indeed by a portion of the Phlogiſton, which is combined with it in a peculiar manner by the means of putrefaction. They ground this opinion chiefly on the analogy or reſemblance which they find between the Nitrous Acid and the Volatile Sulphureous Spirit. Its volatility, its pungent ſmell, its properties of taking fire, and of deſtroying the blue and violet colours of vegetables, ſerve them as ſo many proofs.

Their opinion is the more probable on this account, that even though the Nitrous Acid ſhould actually be produced by vegetable and animal ſubſtances, yet as theſe ſubſtances themſelves draw all their component principles from the earth, and as the Vitriolic Acid is diffuſed through all the ſoils which afford them nouriſhment, there is great reaſon to think that the Nitrous Acid is no other than the Vitriolic Acid altered by the changes and combinations it hath undergone in its paſſage into and thro' thoſe ſubſtances. In 1750 the Royal Academy of Sciences at Berlin propoſed an account of the generation of Nitre as the ſubject for their prize, which was conferred on a Memoir wherein this laſt opinion was ſupported by ſome new and very judicious experiments.

The proceſs by which our Salt-petre makers extract Nitre in quantities, out of rubbiſh and nitrous earths, is very nearly the ſame with that here ſet down: ſo that I ſhall not enter into a particular account of it. I ſhall only take notice of one thing, which it is of ſome conſequence to know; namely, that there is no nitrous earth which does not contain ſea-ſalt alſo. The greateſt quantities of this ſalt are to be found in thoſe earths which have been drenched with urine or other animal excrements. Now as the rubbiſh of old houſes in great cities is in this claſs, it comes to paſs that when the Salt-petre workers evaporate a nitrous lixivium drawn from that rubbiſh, as ſoon as the evaporation is brought to a certain pitch, a great many little cryſtals of ſea-ſalt form in the liquor, and fall to the bottom of the veſſel.

The Salt-petre workers in France call theſe ſaline particles *the Grain*, and take great care to ſeparate them from the liquor, (which as long as it continues hot keeps the ſalt-petre diſſolved) before they ſet it to cryſtallize. This fact ſeems a little ſingular, conſidering that ſea-ſalt diſſolves in water more eaſily than ſalt-petre, and cryſtallizes with more difficulty.

In order to diſcover the cauſe of this phenomenon, we muſt recollect ſome truths delivered in our theoretical Elements. The firſt is, that water can keep but a determinate quantity of any ſalt in ſolution, and that if water fully ſaturated with a ſalt be evaporated, a quantity of ſalt will cryſtallize in proportion to the quantity of water evaporated. The ſecond is, that thoſe ſalts which are the moſt ſoluble in water, particularly thoſe which run in the air, will diſſolve in cold and in boiling water equally; whereas much greater quantities of the other ſalts will diſſolve in hot and boiling water than in cold water. Theſe things being admitted, when we know that ſea-ſalt is one of the firſt ſort, and ſalt-petre of the ſecond, the reaſon why ſea-ſalt precipitates in the preparation of ſalt-petre appears at once. For

When the ſolution of ſalt-petre and ſea-ſalt comes to be evaporated to ſuch a degree that it contains as much ſea-ſalt as it poſſibly can, this ſalt muſt begin to cryſtallize, and continue to do ſo gradually as the evaporation advances. But becauſe at the ſame time it does not contain as much ſalt-petre as it can hold, ſeeing it is capable of diſſolving a much greater quantity thereof when it is boiling hot than when it is cold, this laſt named ſalt will not cryſtallize ſo ſoon. If the evaporation were continued till the caſe of the ſalt-petre came to be the ſame with that of the ſea-ſalt, then the ſalt-petre alſo would begin to cryſtallize gradually in proportion to the water evaporated, and the two ſalts would continue cryſtallizing promiſcuouſly together: but it is never carried ſo far; nor is it ever neceſſary; for as the water cools it becomes more and more incapable of holding in ſolution the ſame quantity of ſalt-petre as when it was boiling hot.

And then comes the very reverſe, with regard to the cryſtallizing of the two ſalts; for then the Salt-petre ſhoots, and not the Sea-ſalt. The reaſon of this fact alſo is founded on what has juſt been ſaid. The Sea-ſalt, of which cold water will diſſolve as much as boiling water, and which owed its cryſtallizing before only to the evaporation, now ceaſes to cryſtallize as ſoon as the evaporation ceaſes; while the Salt-petre, which the water kept diſſolved only becauſe it was boiling hot, is forced to cryſtallize merely by the cooling of the water.

When the ſolution of Salt-petre has yielded as many cryſtals of that Salt as it can yield by cooling, it is again evaporated, and being then ſuffered to cool yields more cryſtals. And thus they continue evaporating and cryſtallizing, till the liquor will afford no more cryſtals. It is plain that as the Salt-petre cryſtallizes, the proportion of Sea-ſalt to the diſſolving liquor increaſes; and as a certain quantity of water evaporates alſo during the time employed in cryſtallizing the Salt-petre, a quantity of Sea-ſalt, proportioned to the water ſo evaporating, muſt cryſtallize in that time: and this is the reaſon why Salt-petre is adulterated with a mixture of Sea-ſalt. It likewiſe follows that the laſt cryſtals of Nitre, obtained from a ſolution of Salt-petre and Sea-ſalt, contain much more Sea-ſalt than the firſt.

From all that has been ſaid concerning the cryſtallization of Salt-petre and Sea-ſalt, it is eaſy to deduce the proper way of purifying the former of theſe two Salts from a mixture of the latter. For this purpoſe the Salt-petre to be refined need only be diſſolved in fair water. The proportion between the two ſalts in this ſecond ſolution is very different from what it was in the former; for it contains no more Sea-ſalt than what had cryſtallized along with the Salt-petre under favour of the evaporation, the reſt having been left diſſolved in the liquor that refuſed to yield any more nitrous cryſtals.

As there is therefore a much greater quantity of Salt-petre than of Sea-ſalt in this ſecond ſolution, it is eaſy to evaporate it to ſuch a degree that a great deal of Salt-petre ſhall cryſtallize, while much more of the water muſt neceſſarily be evaporated before any of the Sea-ſalt will cryſtallize.

However, the Salt-petre is not yet entirely freed from all mixture of Sea-ſalt by this firſt purification; for the cryſtals obtained from this liquor, in which Sea-ſalt is diſſolved, are ſtill encruſted, and, as it were, infected therewith: hence it comes, that, to refine the Salt-petre thoroughly, theſe cryſtallizations muſt be repeated four or five times.

The Salt-petre men commonly content themſelves with cryſtallizing it thrice, and call the produce Salt-petre of the firſt, ſecond, or third ſhoot, according to the number of cryſtallizations it has undergone. But their beſt refined Salt-petre, even that of the third ſhooting, is not yet ſufficiently pure for Chymical experiments that require much accuracy: ſo that it muſt be further purified, but ſtill by the ſame method.

The Nitrous Acid is not pure in the earths and ſtones from which it is extracted. It is combined partly with the very earth in which it is formed, and partly with the Volatile Alkali produced by the putrefaction of the vegetable or animal matters that concurred to its generation. A Fixed Alkali and Quick-lime are added to the lixivium of a nitrous earth, in order to decompoſe the nitrous Salts formed in that earth, and to ſeparate the Acid from the Volatile Alkali and the abſorbent earth with which it is united: thence comes that copious ſediment which appears in the lye at the beginning of the evaporation. Theſe matters form with that Acid a true Nitre, much more capable than the original Nitrous Salts of cryſtallization, detonation, and the other properties which are eſſential thereto. The baſis of Nitre is therefore a Fixed Alkali mixed with a little lime.

The Mother of Nitre, which will yield no more cryſtals, is brown and thick: by evaporation over a fire it is further inſpiſſated, and becomes a dry, ſolid body; which however being left to itſelf ſoon gives, and runs into a liquor. This water ſtill contains a good deal of Nitre, Sea-ſalt, and the Acids of theſe Salts united with an abſorbent earth. It contains moreover a great deal of a fat, viſcid matter, which prevents its cryſtallizing.

All ſaline ſolutions in general, after having yielded a certain quantity of cryſtals, grow thick, and refuſe to part with any more, though they ſtill contain much Salt. They are all called *Mother-waters*, as well as that which hath yielded Nitre. The Mother-waters of different Salts may prove the ſubjects of curious and uſeful enquiries.

If a Fixed Alkali be mixed with the Mother of Nitre, a copious white precipitate immediately falls, which being collected and dried is called *Magneſia*. This precipitate is nothing but the abſorbent earth that was united with the Nitrous Acid, together with a good deal of the lime that was added, and was alſo united with that Acid, from which they are now ſeparated by the Fixed Alkali, according to the uſual laws of affinities.

The Vitriolic Acid poured upon Mother of Nitre cauſes many Acid vapours to riſe, which are a compound of the nitrous and marine Acids, that is, an *Aqua regia*. On this occaſion alſo there falls a large quantity of a white powder, which is ſtill called *Magneſia*; yet it differs from the former in that it is not, like it, a pure abſorbent earth, but combined with the Vitriolic Acid.

An *Aqua regis* may alſo be drawn from nitrous earths by the force of fire only, without the help of any additament.

PROCESS II.

To decompoſe Nitre by means of the Phlogiſton. Nitre fixed by Charcoal. Clyſſus *of Nitre.* Sal Polychreſtum.

TAKE the pureſt Salt-petre in powder; put it into a large crucible, which it may but half fill; ſet the crucible in a common furnace, and ſurround it with coals. When it is red-hot the Nitre will melt, and become as fluid as water. Then throw into the crucible a ſmall quantity of charcoal-duſt: the Nitre and the charcoal will immediately deflagrate with violence; and a great commotion will be raiſed, accompanied with a conſiderable hiſſing, and abundance of black ſmoke. As the charcoal waſtes, the detonation will abate, and ceaſe entirely as ſoon as the coal is quite conſumed.

Then throw into the crucible the ſame quantity of charcoal-duſt as before, and the ſame phenomena will be repeated. Let this coal alſo be conſumed: then add more, and go on in the ſame manner till you can excite no further deflagration; always obſerving to let the burning coal be entirely conſumed before you add any freſh. When no deflagration enſues, the matter contained in the crucible will have loſt much of its fluidity.

OBSERVATIONS.

NITRE will not take fire, unleſs the inflammable matter added to it be actually burning, or the Nitre itſelf red-hot, and ſo thoroughly ignited as immediately to kindle it. Therefore, if you would procure the detonation of Nitre with charcoal, and make uſe of cold charcoal, as in the proceſs, the Nitre in the crucible muſt be red-hot, and in perfect fuſion: but you may alſo uſe live coals, and then the Nitre need not be red-hot.

It is proper that the crucible uſed in this experiment ſhould be only half full; for during the detonation its contents ſwell, and might run over without this precaution. For the ſame reaſon the charcoal-duſt is to be thrown in by little and little; and that firſt put in muſt be entirely conſumed before any freſh be added.

The matter remaining in the crucible after the operation is a very ſtrong Fixed Alkali. Being expoſed to the air it quickly attracts the moiſture thereof, and runs into a liquor. It is called *Alkalizated Nitre*, or to diſtinguiſh it from Nitre alkalizated by other inflammable matters, *Nitre fixed by charcoal*.

However,

However, this Alkali is not abſolutely pure. It ſtill contains a portion of the Nitre that hath not been decompoſed: for when there remains but a little of this Salt mixed with a great quantity of Alkali, which is not inflammable, the Alkali in ſome meaſure ſhelters it, coats it over, and obſtructs that immediate contact with the inflammable matters applied, which is neceſſary to make it deflagrate.

If the Fixed Alkali be deſired perfectly free from any mixture of undecompoſed Nitre, the fire about the crucible muſt be conſiderably increaſed as ſoon as the detonation is entirely over; the matter muſt be made to flow, which requires a much ſtronger heat than would melt Nitre, and kept thus in fuſion for about an hour. After this no perfect Nitre will be found therein: for the little that was left, being unable to abide the force of the fire, as not being extremely fixed, either is entirely diſſipated, or loſes its Acid, which is carried off by the violence of the heat.

Fixed Nitre contains alſo a portion of the earth that conſtituted the baſis of the Nitre, which is no other than the lime employed in its cryſtallization, or elſe ſome of the earth with which its Acid was originally combined, and which it retained in cryſtallizing. When Nitre is deflagrated with ſuch matters as produce aſhes, theſe aſhes likewiſe furniſh a certain quantity of earth, which mixes with the Fixed Alkali. To ſeparate theſe ſeveral earths from the Alkali, nothing more is requiſite than to let them run *per deliquium*, or to diſſolve them in water, and filter the ſolution through brown paper. Whatever is ſaline will paſs through the filtre with the water, and the earthy part will be left upon it.

The Nitrous Acid is not only diſſipated during the deflagration of the Nitre, but is even deſtroyed, and perfectly decompoſed. The ſmoke that riſes during the operation has not the leaſt odour of an Acid. Its nature may be accurately examined by catching it in proper veſſels, and condenſing it into a liquor.

Nitre differs from Sulphur, and from all other inflammable bodies whatever, in this, that the free acceſs of the air is indiſpenſably neceſſary to make any of the others burn; whereas Nitre, and Nitre only, is capable of burning in cloſe veſſels: and this property furniſhes us with the means of collecting the vapours which it diſcharges in deflagration.

For this purpoſe to a tubulated earthen retort you muſt fit two or three large adopters: ſet the retort in a furnace; and under it make a fire ſufficient to keep its bottom moderately red. Then take a ſmall quantity, two or three pinches for example, of a mixture of three parts of Nitre with one of charcoal-duſt, and drop it into the retort through its tube, which muſt be uppermoſt, and immediately ſtopped cloſe. A detonation inſtantly enſues, and the vapours that riſe from the inflamed mixture of Nitre and charcoal, paſſing out through the neck of the retort into the adopters, circulate therein for a while, and at laſt condenſe into a liquor.

When the detonation is over, and the vapours condenſed, or nearly ſo, drop into the retort another equal quantity of the mixture; and repeat this till you find there is liquor enough in the recipients to be examined with eaſe and accuracy. This liquor is almoſt inſipid, and ſhews no tokens of acidity; or at moſt but very ſlight ones. It is called *Clyſſus* of Nitre.

It is eaſy to perceive why ſeveral adopters are required in this experiment, and why a very ſmall quantity of the mixture muſt be introduced into the retort at once. The exploſion, and the quantity of air and vapours diſcharged on this occaſion, would quickly burſt the veſſels, if all theſe precautions were not attended to. This plainly appears from the terrible effects of gun-powder, which is nothing but a compoſition of Nitre, Sulphur, and Charcoal.

Nitre is alſo decompoſed and takes fire by the means of Sulphur; but the circumſtances and the reſult differ widely from thoſe produced therewith by charcoal, or any other inflammable body.

Nitre deflagrates with Sulphur on account of the Phlogiſton which the latter contains. If one part of Sulphur be mixed with two or three parts of Nitre, and the mixture thrown by little and little into a red-hot crucible, upon every projection there ariſes a detonation accompanied with a vivid flame.

The vapours diſcharged on this occaſion have the mingled ſmell of a Sulphureous Spirit and Spirit of Nitre; and if they be collected by means of a tubulated retort, and ſuch an apparatus of veſſels as was uſed in the preceding experiment, the liquor contained in the recipients is found to be an actual mixture of the Acid of Sulphur, the Sulphureous Spirit, and the Acid of Nitre; the firſt being in greater quantity than the other two, and the ſecond greater than the laſt.

Nor is the remainder after detonation a Fixed Alkali, as in the former experiments; but a Neutral Salt, conſiſting of the Acid of Sulphur combined with the Alkali of Nitre; a ſort of Vitriolated Tartar, known in medicine by the name of *Sal Polychreſtum*.

There are evidently two eſſential differences between this laſt experiment and the preceding one. What remains after the deflagration of Nitre with Sulphur is not a Fixed Alkali: and moreover, the vapours emitted in the operation are impregnated with a quantity of the Nitrous Acid; which is not the caſe when Nitre is decompoſed by any other inflammable matter which contains no Vitriolic Acid.

The reaſon of theſe differences is naturally deducible from what hath been already ſaid concerning the properties of the Vitriolic and Nitrous Acids. We have ſeen that by burning Sulphur its Acid is not decompoſed, but only ſeparated from its Phlogiſton. We alſo know that its Acid has a great affinity with Fixed Alkalis. Theſe things being granted, it follows that, as ſoon as the Nitrous Acid quits its Alkaline baſis, by deflagrating with the Phlogiſton of the Sulphur, the Acid of this very Sulphur, being ſet at liberty by that deflagration, muſt unite with the Alkaline baſis deſerted by the Acid of Nitre, and therewith form a Neutral Salt. Hence, inſtead of a Fixed Alkali, we find at the end of the operation a ſort of Vitriolated Tartar; the Acids of Sulphur and of Vitriol being the ſame, as is evident from what hath been above ſaid concerning them.

In order to diſcover the cauſe of the other phenomenon, we muſt recollect two things advanced in our Elements of the Theory; to wit, that the affinity of the Vitriolic Acid with Fixed Alkalis is greater than that of the Nitrous Acid; and again, that the Nitrous Acid is not capable of combining and taking fire with the Phlogiſton, but when it is in the form of a Neutral Salt, that is, when it is united with ſome alkaline, earthy, or metallic baſis. If theſe two principles be applied to the effect in queſtion, the ſolution is eaſy and natural. For, in the deflagration of Nitre with Sulphur, the Phlogiſton is not the only ſubſtance capable of ſeparating the Nitrous Acid from its baſis: the Acid of the Sulphur, more and more of which is ſet at liberty as the Phlogiſton is conſumed, is alſo capable of producing the ſame effect; but with this difference, that the portion of the Nitrous Acid which is detached from its Alkali by the Phlogiſton is at the ſame inſtant ſet on fire and decompoſed by that union; whereas the portion thereof which is ſeparated by the Vitriolic Acid, being when ſo ſeparated incapable of uniting with the Phlogiſton, and of conſuming, therewith, is preſerved entire, and riſes in vapours, together with that portion of the Vitriolic Acid which could not unite with the baſis of the Nitre.

PROCESS III.

To decompoſe Nitre by means of the Vitriolic Acid. The Smoking Spirit of Nitre. Sal de duobus. *The Purification of Spirit of Nitre.*

TAKE equal parts of well purified Nitre and Green Vitriol: dry the Nitre thoroughly, and bruiſe it to a fine powder. Calcine the Vitriol to redneſs: reduce it likewiſe to a very fine powder; and mingle theſe two ſubſtances well together. Put the mixture into an earthen long-neck, or a good glaſs retort coated, of ſuch a ſize that it may be but half full.

Set this veſſel in a reverberating furnace covered with its dome; apply a large glaſs receiver, having a ſmall hole in its body, ſtopped with a little lute. Let this receiver be accurately luted to the retort with the fat lute, and the joint covered with a ſlip of canvas ſmeared with lute made of quicklime and the white of an egg. Heat the veſſels very gradually. The receiver will ſoon be filled with very denſe red vapours, and drops will begin to diſtill from the noſe of the retort.

Continue the diſtillation, encreaſing the fire a little when you obſerve the drops to follow each other but ſlowly, ſo that above two thirds of a minute paſſes between them; and, in order to let out the redundant vapours, open the ſmall hole in the receiver from time to time. Towards the end of the operation raiſe the fire ſo as to make the retort red. When you find that, even when the retort is red-hot, nothing more comes over, unlute the receiver, and without delay pour the liquor it contains

tains into a cryſtal bottle, and cloſe it with a cryſtal ſtopple rubbed in its neck with emery. This liquor will be of a reddiſh yellow colour, ſmoking exceedingly, and the bottle containing it will be conſtantly filled with red fumes like thoſe obſerved in the receiver.

OBSERVATIONS.

THE Vitriolic Acid having a greater affinity with Fixed Alkalis than with any other ſubſtance, the Phlogiſton excepted, and being in the Vitriol united with a ferruginous baſis, will naturally quit that baſis to join with the Fixed Alkali of the Nitre; the Acid whereof being weaker than the Vitriolic, as we have already obſerved on ſeveral occaſions, muſt needs be thereby expelled from its baſis. The Nitre therefore is decompoſed by the Vitriol, and its Acid being ſet at liberty, is carried up by the force of the fire.

Indeed the Nitrous Acid, being thus ſeparated from its alkaline baſis, might be expected to combine with the ferruginous baſis of the Vitriol: but as it has, like all other Acids, much leſs affinity with Metallic ſubſtances than with Alkalis, even a moderate degree of fire is ſufficient to ſeparate it from them. Moreover, this Acid hath either no effect, or very little, upon iron that has loſt much of its Phlogiſton by contracting an union with any Acid; which is the caſe of the ferruginous baſis of Vitriol.

By the proceſs here delivered a very ſtrong, perfectly dephlegmated, and vaſtly ſmoking Spirit of Nitre is obtained. If the precautions of drying the Nitre and calcining the Vitriol be neglected, the Acid that comes over, greedily attracting the water contained in theſe ſalts, will be very aqueous, will not ſmoke, and will be almoſt colourleſs; with a very ſlight tinge of lemon.

The fumes of highly concentrated Spirit of Nitre, ſuch as that obtained by the above proceſs, are light, corroſive, and very dangerous to the lungs; being no other than the moſt dephlegmated part of the Nitrous Acid. The perſon therefore who unlutes the veſſels, or pours the liquor out of the receiver into the bottle, ought with the greateſt caution to avoid drawing them in with his breath; and for that reaſon ought to place himſelf ſo that a current of air, either natural or artificial, may carry them off another way. It is alſo neceſſary that care be taken, during the operation, to give the vapours a little vent every now and then, by opening the ſmall hole in the recipient; for they are ſo elaſtic, that, if too cloſely confined, they will burſt the veſſels.

When the operation is over, you will find a red maſs at the bottom of the retort, caſt as it were in a mould. This is a Neutral Salt of the nature of Vitriolated Tartar, reſulting from the union of the Acid of the Vitriol with the Alkaline baſis of the Nitre.

The ferruginous baſis of the Vitriol, which is mixed with this ſalt, gives it the red colour. To ſeparate it therefrom, you muſt pulveriſe it, diſſolve it in boiling water, and filter the ſolution ſeveral times through brown paper; becauſe the ferruginous earth of the vitriol is ſo fine, that ſome of it will paſs through the firſt time. When the ſolution is very clear, and depoſites no ſediment, let it be ſet to ſhoot, and it will yield cryſtals of Vitriolated Tartar; to which Chymiſts have given the peculiar title of *Sal de duobus*.

In this *Caput mortuum* we frequently find, beſides the ferruginous earth of Vitriol, a portion of Nitre and Vitriol not decompoſed; either becauſe the two ſalts were not thoroughly mingled, or becauſe the

Fire was not raiſed high enough towards the end of the operation.

Nitre may alſo be decompoſed, and its Acid obtained, by the interpoſition of any of the other Vitriols, Alums, Gypſums, Boles, Clays; in ſhort, by means of any compound in which the Vitriolic Acid is found, provided it have not a Fixed Alkali for its baſis.

The diſtillers of *Aqua fortis*, who make large quantities at a time, and who uſe the leaſt chargeable methods, do their buſineſs by the means of earths impregnated with the Vitriolic Acid; ſuch as Clays and Boles. With theſe earths they accurately mix the Nitre from which they intend to draw their Spirit: this mixture they put into large oblong earthen pots, having a very ſhort curved neck, which enters a recipient of the ſame matter and form. Theſe veſſels they place in two rows oppoſite to each other in long furnaces, and cover them over with bricks cemented with Windſor-loam, which ſerves for a reverberatory: then they light the fire in the furnace, making it at firſt very ſmall, only to warm the veſſels; after which they throw in wood, and raiſe the fire till the pots grow quite red-hot, in which degree they keep it up till the diſtillation is entirely finiſhed.

The Acid of Nitre may alſo be ſeparated from its baſis by means of the pure Vitriolic Acid. For this purpoſe the Nitre from which you mean to extract the Acid muſt be finely pulverized, put into a glaſs retort, and a third of its weight of concentrated Oil of Vitriol poured on it: the retort muſt be placed in a reverberating furnace, and a receiver, like that uſed in the preceding operation, expeditiouſly applied.

As ſoon as the Oil of Vitriol touches the Nitre the mixture grows hot, and copious red fumes begin to appear: ſome drops of the Acid come over even before the fire is kindled in the furnace.

On this occaſion the fire muſt be moderate; becauſe the Vitriolic Acid, being clogged by no baſis, acts upon the Nitre much more briſkly, and with much greater effect, than when it is not pure.

This operation may be performed by a ſand heat; which is a ſpeedy and commodious way of obtaining the Nitrous Acid. In other reſpects the precautions recommended in the preceding experiment muſt be carefully obſerved here, both in diſtilling the Acid and in taking it out of the receiver.

The Spirit of Nitre extracted by this method is as ſtrong, and ſmokes as much, as that obtained by calcined Vitriol, provided the Oil of Vitriol made uſe of be well concentrated; but it is generally tainted by the admixture of a ſmall portion of the Vitriolic Acid, which, having no baſis of its own to reſtrain it, is carried up by the heat before it can lay hold of the baſis of the Nitre.

There are ſeveral experiments in Chymiſtry that ſucceed equally well whether the Nitrous Acid be or be not thus adulterated with a mixture of the Vitriolic Acid; but there are ſome, as we ſhall ſee, that will not ſucceed without a Spirit of Nitre ſo mixed. If the Acid be diſtilled with a view to ſuch experiments, it muſt be kept as it is. But moſt experiments require the Spirit of Nitre to be abſolutely pure; and if it be intended for ſuch, it muſt be perfectly cleanſed from the Vitriolic taint.

This is eaſily effected by mixing your Spirit with very pure Nitre, and diſtilling it a ſecond time. The Vitriolic Acid, with which this Spirit of Nitre is adulterated, coming in contact with a great quantity of undecompoſed Nitre, unites with its Alkaline baſis, and expells a proportionable quantity of the Nitrous Acid.

In the retort made uſe of to diſtill the Nitrous Acid, by means of the pure Vitriolic Acid, is found a *Caput mortuum* differing from that left after the diſtillation of the ſame Acid by the interpoſition of Vitriol, in as much as it contains no red ferruginous earth. This is a very white ſaline maſs, moulded in the bottom of the retort: if you pound it, diſſolve it in boiling water, and evaporate the ſolution, it will ſhoot into cryſtals of Vitriolated Tartar: ſometimes alſo it contains a portion of undecompoſed Nitre, which ſhoots after the Vitriolated Tartar, becauſe it is much more ſoluble in water.

CHAP. III.

Of the MARINE ACID.

PROCESS I.

To extract Sea-Salt from Sea-Water, and from Brine-Springs. Epſom Salt.

FILTER the ſalt water from which you intend to extract the Salt; evaporate it by boiling till you ſee on its ſurface a dark pellicle: this conſiſts wholly of little cryſtals of ſalt juſt beginning to ſhoot: now ſlacken the fire, that the brine may evaporate more ſlowly, and without any agitation. The cryſtals, which at firſt were very ſmall, will become larger, and form hollow truncated pyramids, the apices whereof will point downwards, and their baſes be even with the ſurface of the liquor.

Theſe pyramidal cryſtals are only collections of ſmall cubical cryſtals concreted into this form.

When they have acquired a certain magnitude they fall to the bottom of the liquor. When they come to be in ſuch heaps as almoſt to reach the ſurface of the liquor, decant it from them, and continue the evaporation till no more cryſtals of Sea-ſalt will ſhoot.

OBSERVATIONS.

THE Acid of Sea-ſalt is ſcarce ever found, either in Sea-water or in the earth, otherwiſe than united with a fixed Alkali of a particular kind, which is its natural baſis; and conſequently it is in the form of a Neutral Salt. This Salt is plentifully diſſolved in the waters of the ocean, and when obtained therefrom bears the name of *Sea-ſalt* It is alſo found in the earth in vaſt cryſtalline maſſes, and is then called *Sal-Gem*: ſo that Sea-Salt and Sal-Gem are but one and the ſame ſort of Salt, differing very little from each other, except as to the places where they are found.

In the earth are alſo found ſprings and fountains, whoſe waters are ſtrong brines, a great deal of Sea-ſalt being diſſolved in them. Theſe ſprings either riſe directly from the Sea, or run through ſome mines of Sal-Gem, of which they take up a quantity in their paſſage..

As the ſame, or at leaſt nearly the ſame, quantity of Sea-ſalt will continue diſſolved in cold water as boiling water will take up, it cannot ſhoot, as Nitre does, by the mere cooling of the water in which it is diſſolved: it cryſtallizes only by the means of evaporation, which continually leſſens the proportion of the water to the Salt; ſo that it is always capable of containing juſt ſo much the leſs Sea-ſalt the more there is cryſtallized.

The brine ſhould not boil after you perceive the pellicle of little cryſtals beginning to form on its ſurface; for the calmneſs of the liquor allows them to form more regularly, and become larger. Nor after this ſhould the evaporation be hurried on too faſt; for a ſaline cruſt would form on the liquor, which, by preventing the vapours from being carried off, would obſtruct the cryſtallization.

If the evaporation be continued after the liquor ceaſes to yield any cryſtals of Sea-ſalt, other cryſtals will be obtained of an oblong four-ſided form, which have a bitter taſte, and are almoſt always moiſt. This ſort of Salt is known by the name of *Epſom Salt*, which it owes to a ſalt ſpring in England, from the water of which it was firſt extracted. This Salt, or rather ſaline compound, is a congeries of Glauber's Salt and Sea-ſalt, in a manner confounded together, and mixed with ſome of the Mother of Sea-ſalt, in which is contained a kind of bituminous matter. Theſe two Neutral Salts, which conſtitute the Epſom Salt, may be eaſily ſeparated from each other, by means of cryſtallization only. Epſom Salt is purgative and bitter; and therefore named *Sal catharticum amarum*, or bitter purging Salts.

There are different methods uſed in great works for obtaining Sea-ſalt out of water in which it is diſſolved. The ſimpleſt and eaſieſt is that practiſed in France, and in all thoſe countries which are not colder. On the ſea ſhore they lay out a ſort of broad ſhallow pits, pans, or rather ponds, which the ſea fills with the tide of flood. When the ponds are thus filled, they ſtop their communication with the ſea, and leave the water to evaporate by the heat of the ſun; by which means all the Salt contained in it neceſſarily cryſtallizes. Theſe pits are called *Salt Ponds*. Salt can be made in this way in the ſummer-time only; at leaſt in France, and other countries of the ſame temperature: for during the winter, when the ſun has leſs power and rains are frequent, this method is not practicable.

For this reaſon, as it often rains in the province of Normandy, the inhabitants take another way to extract Salt from ſea-water. The labourers employed for this purpoſe raiſe heaps of ſand on the ſhore, ſo that the tide waters and drenches them when it flows, and leaves the ſand dry when it ebbs. During the interval between two tides of flood the ſun and the air eaſily carry off the moiſture that was left, and ſo the ſand remains impregnated with all the Salt that was contained in the evaporated water. Thus they let it acquire as much ſalt as it can by ſeveral returns of flood, and then waſh it out with freſh water, which they evaporate over a fire in leaden boilers.

To obtain the Salt from brine-ſprings, the water need only be evaporated: but as ſeveral of theſe ſprings contain too little Salt to pay the charges that would be incurred, if the evaporation were effected by the force of fire only, the manufacturers have fallen upon a leſs expenſive method of getting rid of the greateſt part of the water, and preparing the brine for cryſtallization, in much leſs time, and with much leſs fire, than would otherwiſe have been neceſſary.

The method conſiſts in making the water fall from a certain heighth on a great many ſmall ſpars of wood, which divide it into particles like rain. This is performed under ſheds open to all the winds, which paſs freely through this artificial ſhower. By this means the water preſents to the air a great extent of ſurface, being indeed reduced almoſt entirely to ſurface, and the evaporation is carried on with great eaſe and expedition. The water is raiſed by pumps to the heighth from which it is intended to fall *.

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* The Marquis de Montalembert, in a Memoir read before the Academy of Sciences, propoſes a new method of effecting

PROCESS II.

Experiments concerning the decompoſition of Sea-ſalt, by means of the Phlogiſton. Kunckel's *Phoſphorus.*

"OF pure urine that has fermented five or ſix "days take a quantity in proportion to "the quantity of Phoſphorus you intend to make; "it requires about one third part of a hogſhead to "make a dram of Phoſphorus. Evaporate it in "iron pans, till it become clotted, hard, black, "and nearly like chimney-ſoot; at which time it "will be reduced to about a ſixtieth part of its ori"ginal weight before evaporation.

"When the urine is brought to this condition "put it in ſeveral portions into ſo many iron pots, "under which you muſt keep a pretty briſk fire "ſo as to make their bottoms red, and ſtir it in"ceſſantly till the volatile ſalt and the fetid oil be "almoſt wholly diſſipated, till the matter ceaſe to "emit any ſmoke, and till it ſmell like peach-bloſ"ſoms. Then put out the fire, and pour on the "matter, which will now be reduced to a powder, "ſomewhat more than twice its weight of warm wa"ter. Stir it about in this water, and leave it to "ſoak therein for twenty four hours. Pour off the "water by inclination; dry the drenched matter, "and pulverize it. The previous calcination carries "off from the matter about a third of its weight, "and the lixiviation waſhes out half the remainder.

"With what remains thus calcined, waſhed, "and dried, mix half its weight of gravel, or yel-

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theſe evaporations, together with ſome conſiderable improvements in the ſtructure and diſpoſition of the buildings neceſſary for that purpoſe. They are called by the French *Batiments de Graduation*; which may properly enough be rendered *Brine-houſes.*

" low freeſtone raſped, having ſifted out and thrown " away all the fineſt particles. River-ſand is not " proper on this occaſion, becauſe it flies in a hot " fire. Then add to this mixture a ſixteenth part of " its weight of charcoal, made of beech, or of any " other wood except oak, becauſe that alſo flies. " Moiſten the whole with as much water as will " bring it to a ſtiff paſte, by working and kneading " it with your hands: now introduce it into your " retort, taking care not to daub its neck. The re- " tort muſt be of the beſt earth, and of ſuch a ſize, " that when your matter is in it, a full third thereof " ſhall ſtill be empty.

" Place your retort, thus charged, in a reverbe- " rating furnace, ſo proportioned, that there may " be an interval of two inches all round between the " ſides of the furnace and the bowl of the retort, " even where it contracts to form the neck, which " ſhould ſtand inclined at an angle of ſixty degrees. " Stop all the apertures of the furnace, except the " doors of the fire-place and aſh-hole.

" Fit on to the retort a large glaſs ballon two " thirds full of water, and lute them together, as " in diſtilling the Smoking Spirit of Nitre. In the " hinder part of this ballon, a little above the ſur- " face of the water, a ſmall hole muſt be bored. " This hole is to be ſtopped with a ſmall peg of " birch-wood, which muſt ſlip in and out very ea- " ſily, and have a ſmall knob to prevent its falling " into the ballon. This peg is to be pulled out from " time to time, that by applying the hand to the " hole it may be known whether the air, rarefied " by the heat of the retort, iſſues out with too " much or too little force.

" If the air ruſhes out with too much rapidity, " and with a hiſſing noiſe, the door of the aſh-hole " muſt be entirely ſhut, in order to ſlacken the fire. " If it do not ſtrike pretty ſmartly againſt the hand, "that door muſt be opened wider, and large coals "thrown into the fire-place to quicken the fire im"mediately.

"The operation uſually laſts four and twenty "hours; and the following ſigns ſhew that it will "ſucceed, provided the retort reſiſt the fire.

"You muſt begin the operation with putting "ſome unlighted charcoal in the aſh-hole, and a "little lighted charcoal at the door thereof, in or"der to warm the retort very ſlowly. When the "whole is kindled, puſh it into the aſh-hole, and "cloſe the door thereof with a tile. This moderate "heat brings over the phlegm of the mixture. The "ſame degree of fire muſt be kept up four hours, "after which ſome coals may be laid on the grate of "the fire-place, which the fire underneath will kin"dle by degrees. With this ſecond heat brought "nearer the retort, the ballon grows warm, and is "filled with white vapours, which have the ſmell of "fetid oil. In four hours after this veſſel will grow "cool and clear; and then you muſt open the door "of the aſh-hole one inch, throw freſh coals into "the fire-place every three minutes, and every time "ſhut the door of it, leſt the cold air from without "ſhould ſtrike againſt the bottom of the retort and "crack it.

"When the fire has been kept up to this degree "for about two hours, the inſide of the ballon be"gins to be netted over with a volatile ſalt of a "ſingular nature, which cannot be driven up but "by a very violent fire, and which ſmells pretty "ſtrong of peach-kernels. Care muſt be taken "that this concrete ſalt do not ſtop the little hole in "the ballon: for in that caſe it would burſt, the "retort being then red-hot, and the air exceedingly "rarefied. The water in the ballon, being heated "by the vicinity of the furnace, exhales vapours

" which diſſolve this ſprigged ſalt, and the ballon " clears up in half an hour after it has ceaſed riſing.

" In about three hours from the firſt appearance " of this ſalt, the ballon is again filled with new va- " pours, which ſmell like Sal Ammoniac thrown " upon burning coals. They condenſe on the ſides " of the receiver into a ſalt which is not branch- " ed like the former, but appears in long perpendi- " cular ſtreaks, which the vapours of the water do " not diſſolve. Theſe white vapours are the fore- " runners of the Phoſphorus, and a little before they " ceaſe to riſe they loſe their firſt ſmell of Sal Am- " moniac, and acquire the odour of garlick.

" As they aſcend with great rapidity, the little " hole muſt be frequently opened, to obſerve whe- " ther the hiſſing be not too ſtrong; for in that caſe " it would be neceſſary to ſhut the door of the aſh- " hole quite cloſe. Theſe white vapours continue " two hours. When you find they ceaſe riſing, " make a ſmall paſſage through the dome, by open- " ing ſome of its regiſters, that the flame may juſt " begin to draw. Keep up the fire in this mean " ſtate till the firſt volatile Phoſphorus begin to ap- " pear.

" This appears in about three hours after the " white vapours firſt begin to riſe. In order to diſ- " cover it, pull out the little birchen peg once eve- " ry minute, and rub it againſt ſome hot part of the " furnace, where it will leave a trail of light, if " there be any Phoſphorus upon it.

" Soon after you obſerve this ſign, there will iſ- " ſue out through the little hole of the ballon a " ſtream of blueiſh light, which continues of a " greater or ſhorter extent to the end of the opera- " tion. This ſtream or ſpout of light does not burn. " If you hold your finger againſt it for twenty or " thirty ſeconds, the light will adhere to it; and if

" you rub that finger over your hand, the light " will beſmear it, and render it luminous.

" But from time to time this ſtreamer darts out " to the length of ſeven or eight inches, ſnapping " and emitting ſparks of fire; and then it burns all " combuſtible bodies that come in its way. When " you obſerve this, you muſt manage the fire very " warily, and ſhut the door of the aſh-hole quite " cloſe, yet without ceaſing to throw coals into the " fire-place every two minutes.

" The Volatile Phoſphorus continues two hours; " after which the little ſpout of light contracts to " the length of a line or two: and now is the time, " for puſhing your fire to the utmoſt: immediately " ſet the door of the aſh-hole wide open, throw bil-" lets of wood into it, unſtop all the regiſters of the " reverberatory, ſupply the fire-place with large " coals every minute: in ſhort, for ſix or ſeven " hours all the inſide of the furnace muſt be kept " of a white heat, ſo that the retort ſhall not be " diſtinguiſhable.

" In this fierce extremity of heat the true Phoſ-" phorus diſtills like an oil, or like melted wax: " one part thereof floats on the water in the reci-" pient, the other falls to the bottom. At laſt, " the operation is known to be quite over when the " upper part of the ballon, in which the volatile Phoſ-" phorus appears condenſed in a blackiſh film, begins " to grow red: for this ſhews that the Phoſphorus is " burnt where the red ſpot appears. You muſt now " ſtop all the regiſters, and ſhut all the doors of the fur-" nace, in order to ſmother the fire; and then cloſe up " the little hole in the ballon with fat lute or bees-" wax. In this condition the whole muſt be left " for two days; becauſe the veſſels muſt not be ſe-" parated till they are perfectly cold, leſt the Phoſ-" phorus ſhould take fire.

“ As ſoon as the fire is out, the ballon, which is then in the dark, preſents a moſt agreeable object: all the empty part thereof above the water ſeems filled with a beautiful blue light; which continues for ſeven or eight hours, or as long as the ballon keeps warm, never diſappearing till it is cooled.

“ When the furnace is quite cold take out the veſſels, and ſeparate them from each other as neatly as poſſible. With a linen cloth wipe away all the black ſtuff you find in the mouth of the ballon; for if that filth ſhould mix with the Phoſphorus, it would hinder it from being tranſparent when moulded. This muſt be done with great expedition: after which pour into the ballon two or three quarts of cold water, to accelerate the precipitation of the Phoſphorus that ſwims at top. Then agitate the water in the ballon, to rinſe out all the Phoſphorus that may ſtick to the ſides; pour out all the water thus ſhaken and turbid, into a very clean earthen pan, and let it ſtand till it grows clear. Then decant this firſt uſeleſs water, and on the blackiſh ſediment, left at the bottom of the pan, pour ſome boiling water to melt the Phoſphorus; which thereupon unites with the fuliginous matter, or volatile Phoſphorus, that precipitates with it, both together forming a maſs of the colour of ſlate. When this water, in which you have melted the Phoſphorus, is cool enough, take out the Phoſphorus, throw it into cold water, and therein break it into little bits in order to mould it.

“ Then take a matras, having a long neck ſomewhat wider next the body than at its mouth: cut off half the body, ſo as to make a funnel of the neck-part, the ſmaller end of which muſt be ſtopped with a cork. The firſt mould being thus prepared, plunge it endwiſe, with its "mouth uppermoſt, in a veſſel full of boiling water, "and fill it with that water. Into this funnel throw "the little bits of your ſlate-like maſs, which will "melt again in this hot water, and fall ſo melted "to the bottom of the tube. Stir this melted mat"ter with an iron wire, to promote the ſeparation "of the Phoſphorus from the fuliginous matter "with which it is fouled, and which, being leſs "ponderous than the Phoſphorus, will gradually "riſe above it towards the upper part of the cy"linder.

"Keep the water in the veſſel as hot as at firſt, "till on taking out the tube you ſee the Phoſpho"rus clean and tranſparent. Let the clear tube "cool a little, and then ſet it in cold water, where "the Phoſphorus will congeal as it cools. When "it is perfectly congealed, pull out the cork, and "with a ſmall rod, near as big as the tube, puſh the "cylinder of Phoſphorus towards the mouth of the "funnel, where the feculency lies. Cut off the "black part of the cylinder, and keep it apart: for "when you have got a quantity thereof, you may "melt it over again in the ſame manner, and ſepa"rate the clean Phoſphorus which it ſtill contains. "As to the reſt of the cylinder which is clean and "tranſparent, if you intend to mould it into ſmaller "cylinders, you may cut it in ſlices, and melt it "again by the help of boiling water in glaſs tubes "of ſmaller dimenſions."

OBSERVATIONS.

THIS proceſs for making Phoſphorus is copied from the Memoirs of the Academy of Sciences for the Year 1737; where it is deſcribed by M. Hellot, with ſo much accuracy, clearneſs, and preciſion, that I thought I could not do better than tranſcribe it, without departing from the author's own expreſſions, for the ſake of ſuch as may not have thoſe

Memoirs. We ſhall take occaſion, in theſe obſervations, to point out ſome eſſential circumſtances which I have omitted in the deſcription of the Proceſs, that I might not break the connection between the phenomena that happen in the courſe of this experiment.

It is proper to obſerve, in the firſt place, that one of the moſt uſual cauſes of miſcarriage in this operation is a defect of the requiſite qualities in the retort employed. It is abſolutely neceſſary to have that veſſel made of the beſt earth, and ſo well made that it ſhall be capable of reſiſting the utmoſt violence of fire, continued for a very long time; as appears by the deſcription of the proceſs. The retorts commonly ſold by potters, and other earthen ware-men, are not fit for this operation; and Mr Hellot was obliged to ſend to Heſſe-Caſſel for ſuch as he wanted.

" We ſhall, in the ſecond place, obſerve with " M. Hellot that, before you ſet your retort in " the furnace, it is proper to make an eſſay of your " matter, to ſee if there be reaſon to hope for ſucceſs. For this purpoſe put about an ounce thereof into a ſmall crucible, and heat it till the veſſel " be red. The mixture, after having ſmoked, " ought to chop or crack without puffing up, or even riſing in the leaſt. From theſe cracks will iſſue " undulating flames, white and blueiſh, darting upwards with rapidity. This is the firſt volatile " Phoſphorus, which occaſions all the danger of " the operation. When theſe firſt flaſhes are over, " increaſe the heat of your matter by laying a large " live coal upon the crucible. You will then ſee " the ſecond Phoſphorus, like a luminous, ſteady " vapour, of a colour inclining to violet, covering " the whole ſurface of the matter: it continues for " a very long time, and diffuſes a ſmell of garlick, " which is the diſtinguiſhing odour of the Phoſphorus you are ſeeking.

" When this luminous vapour is entirely gone, " pour the red-hot matter out of the crucible upon " an iron plate. If you do not find one drop of ſalt " in fuſion, but that, on the contrary, the whole falls " readily into powder, 'tis a proof that your matter " was ſufficiently lixiviated, and that it contains " no more fixed Salt, or Sea-ſalt, if you will, than " is requiſite. If you find on the plate a drop of " ſalt coagulated, it ſhews that there is too much " left in it, and that there is danger of your miſcarrying " in the operation; becauſe the redundant " ſalt would corrode, and eat through the retort. " In this caſe your matter muſt be waſhed again, " and then ſufficiently dried."

Our third obſervation ſhall be concerning the furnace proper to be employed in this operation. This furnace muſt be ſo conſtructed, that within a narrow compaſs it may give a heat at leaſt equal to that of a glaſs-houſe furnace, or rather greater, eſpecially during the laſt ſeven or eight hours of the operation. M. Hellot in his Memoir gives an exact deſcription of ſuch a furnace.

" As certain accidents may happen in the courſe " of the operation, ſome precautions are to be taken " againſt them. For inſtance, if the ballon ſhould " break while the Phoſphorus is diſtilling, and any " of it ſhould fall on combuſtible bodies, it would " ſet them on fire, and probably burn the laboratory, " becauſe it is not to be extinguiſhed without the " greateſt difficulty. The furnace muſt therefore be " erected under ſome vault, or upon a bed of brickwork " raiſed under ſome chimney that draws well: " nor muſt any furniture or utenſil of wood be left " near it. If a little flaming Phoſphorus ſhould fall " on a man's legs or hands, in leſs than three minutes " it would burn its way to the very bone. In " ſuch a caſe nothing but urine will ſtop its progreſs.

"If the retort crack while the Phoſphorus is "diſtilling, there is an unſucceſsful end of your "operation. It is eaſy to perceive this by the ſtink "of garlick which you will ſmell about the fur-"nace; and moreover, the flame that iſſues thro' "the apertures of the reverberatory will be of a "beautiful violet colour. The Acid of Sea-ſalt al-"ways gives this colour to the flame of ſuch matters "as are burnt along with it. But if the retort "break before the Phoſphorus hath made its ap-"pearance, its contents may be ſaved by throwing "a number of cold bricks into the fire-place, and "upon them a little water to quench the fire at "once." All theſe uſeful obſervations we owe alſo to M. Hellot.

The Phoſphorus here deſcribed was firſt diſcovered by a citizen of Hamburgh named Brandt, who worked upon urine in ſearch of the Philoſopher's ſtone. Afterwards two other ſkilful Chymiſts, who knew nothing more of the proceſs than that Phoſphorus was obtained from urine, or in general from the human body, likewiſe endeavoured to diſcover it; and each of them ſeparately did actually make the diſcovery. Theſe two Chymiſts were Kunckel and Boyle.

The former perfected the diſcovery, and found out a method of making it in conſiderable quantities at a time; which occaſioned it to be called *Kunckel's Phoſphorus.* The other, who was an Engliſh gentleman, had not time to bring his diſcovery to perfection, and contented himſelf with lodging a voucher of his having diſcovered it in the hands of the Secretary of the Royal Society of London, who gave him a certificate thereof.

"Though Brandt, ſays M. Hellot, who had be-"fore this ſold his ſecret to a Chymiſt named Krafft, "ſold it afterwards to ſeveral other perſons, and e-"ven at a very low rate; and though Mr Boyle "publiſhed the proceſs for making it; yet it is ex-"tremely probable that both of them kept in their "own hands the maſter-key; I mean, *the particu-"lar management neceſſary to make the operation ſuc-"ceed*: for till Kunckel found it out, no other Chy-"miſt ever made any conſiderable quantity thereof, "except Mr. Godfrey Hankwitz, an Engliſh Chy-"miſt, to whom Mr. Boyle revealed the whole "myſtery.

"Nevertheleſs, continues he, we are very far "from alledging that all thoſe who have deſcribed "this operation meaned to impoſe upon the world: "but we conceive that moſt of them having obſerv-"ed luminous vapours in the ballon, and ſome "ſparks about the juncture of the veſſels, were con-"tented with thoſe appearances. And thus it came "to paſs, that, after Kunckel and Boyle died, M. "Godfrey Hankwitz was the only Chymiſt that "could ſupply Europe therewith; on which ac-"count it is likewiſe very well known by the name "of *Engliſh Phoſphorus*."

Almoſt all the Chymiſts conſider Phoſphorus as a ſubſtance conſiſting of the Acid of Sea-ſalt combined with the Phlogiſton, in the ſame manner as Sulphur conſiſts of the Vitriolic Acid combined with the Phlogiſton. This opinion is founded on the following principles.

Firſt, Urine abounds with Sea-ſalt, and contains alſo a great deal of Phlogiſton: now theſe are the ingredients of which they conjecture Phoſphorus to be compoſed.

Secondly, Phoſphorus has many of the properties of Sulphur; ſuch as being ſoluble in oils; melting with a gentle heat; being very combuſtible; burning without any ſoot; giving a vivid and blueiſh flame; and laſtly, leaving an acid liquor when burnt: ſenſible proofs that it differs from Sulphur in nothing but the nature of its Acid.

Thirdly, this Acid of Phoſphorus, being mixed with a ſolution of ſilver in Spirit of Nitre, precipitates the ſilver, and this precipitate is a true *Luna cornea*, which appears to be more volatile even than the common ſort; as M. Hellot tells us, who made the experiment. This fact proves inconteſtably that the Acid of Phoſphorus is of the ſame nature with that of Sea-ſalt: for all Chymiſts know that the property of precipitating ſilver in a *Luna cornea* belongs to the Marine Acid only.

Fourthly, M. Stahl obſerves that, if Sea-ſalt be caſt on live coals, they inſtantly burn with great activity; that they emit a very vivid flame, and are much ſooner conſumed than if none of this Salt had touched them; that Sea-ſalt in ſubſtance, which will bear the violence of fire a conſiderable time when fuſed in a crucible, without ſuſtaining any ſenſible diminution, yet evaporates very quickly, and is reduced to white flowers, by the immediate contact of burning coals; and laſtly, that the flame which riſes on this occaſion is of a blue colour inclining to violet, eſpecially if it be not thrown directly on the coals themſelves, but kept in fuſion amidſt burning coals, in a crucible ſo placed that the vapour of the Salt may join with the enflamed Phlogiſton as it riſes from the coals.

Theſe experiments of Mr Stahl's prove that the Phlogiſton acts upon the Acid of Sea-ſalt, even while it is combined with its alkaline baſis. The flame that appears on this occaſion may be conſidered as an imperfect Phoſphorus: and indeed its colour is exactly like that of Phoſphorus.

All the facts above related evince that the Acid of Phoſphorus is akin to that of Sea-ſalt; or rather that it is the very ſame. But there are other facts which prove that this Acid undergoes ſome change at leaſt, ſome peculiar preparation, before it enters into the compoſition of a true Phoſphorus, and that, when extricated therefrom by burning, it is not a pure Acid of Sea-ſalt, but is ſtill adulterated with a mixture of ſome other ſubſtance, which makes it conſiderably different from that Acid. For theſe obſervations we are obliged to M. Marggraff, of the Academy of Sciences at Berlin, a celebrated Chymiſt. I ſhall preſently give an account of his principal experiments as ſuccinctly as poſſible.

M. Marggraff hath alſo publiſhed a proceſs for making Phoſphorus, and aſſures us that by means thereof we may obtain in leſs time, with leſs heat, leſs trouble, and leſs expence, a greater quantity of Phoſphorus than by any other method. His operation is this:

He takes two pounds of Sal Ammoniac in powder, which he mixes accurately with four pounds of Minium. This mixture he puts into a glaſs retort, and with a graduated fire draws off a very ſharp, volatile, urinous ſpirit.

We obſerved in our theoretical Elements that ſome metallic ſubſtances have the property of decompoſeing Sal Ammoniac, and ſeparating its volatile Alkali; concerning which phenomenon we there gave our opinion. Minium, which is a calx of lead, is one of thoſe metallic ſubſtances. In this experiment it decompoſes the Sal Ammoniac, and ſeparates its volatile Alkali: what remains in the retort is a combination of the Minium with the Acid of the Sal Ammoniac, which is well known to be the ſame with the Marine Acid; and conſequently the reſidue of this operation is a ſort of *Plumbum corneum.*

The quantity thereof is four pounds eight ounces. Of this he mixes three pounds with nine or ten pounds of urine, that has ſtood putrefying for two months, evaporated to the conſiſtence of honey. Theſe he mixes by little and little in an iron pan over the fire, ſtirring the mixture from time to time. Then he adds half a pound of charcoal duſt, and evaporates the matter, kept continually ſtirring, till the whole be brought to a black powder. He next diſtills the mixture in a glaſs retort with degrees of fire, which he raiſes towards the end ſo as to make the retort red-hot, in order to expell all the urinous ſpirit, ſuperfluous oil, and ammoniacal ſalt. The diſtillation being finiſhed, there remains nothing in the retort but a very friable *caput mortuum.*

This remainder he pulveriſes again, and throws a pinch thereof on live coals, thereby to diſcover whether or no the matter be rightly prepared, and in order for yielding Phoſphorus. If it be ſo, it preſently emits an arſenical odour, and a blue undulating flame, which paſſes over the ſurface of the coals like a wave.

Being thus aſſured of the ſucceſs of his operation, he puts one half of his matter, in three equal parts, into three ſmall earthen German retorts, capable of holding about eighteen ounces of water a-piece. Theſe three retorts, none of which is above three quarters full, he places together in one reverberatory furnace, built much like thoſe we have deſcribed, except that it is ſo conſtructed as to hold the three retorts diſpoſed in one line. To each retort he lutes a recipient ſomething more than half full of water, ordering the whole in ſuch a manner, that the noſes of his retorts almoſt touch the ſurface of the water.

He begins the diſtillation with warming the retorts ſlowly, for about an hour, by a gentle heat. When that time is elapſed he raiſes the fire gradually, ſo that in half an hour more the coals begin to touch the bottoms of the retorts. He continues throwing coals into the furnace by little and little, till they riſe half way the heighth of the retorts; and in this he employs another half hour. Laſtly, in the next half hour he raiſes the coals above the bowls of the retorts.

Then the Phoſphorus begins to aſcend in clouds: on this he inſtantly increaſes the heat of the fire as much as poſſible, filling the furnace quite up with coals, and making the retorts very red. This degree of fire cauſes the Phoſphorus to diſtill in drops which fall to the bottom of the water. He keeps up this intenſe heat for an hour and half, at the end of which the operation is finiſhed; ſo that it laſts but four hours and a half in all: nay, he further aſſures us that an artiſt, well verſed in managing the fire, may perform it in four hours only. In the ſame manner he diſtils the ſecond moiety of his mixture in three other ſuch retorts.

The advantage he finds in making uſe of ſeveral ſmall retorts, inſtead of a ſingle large one, is that the heat penetrates them with more eaſe, and the operation is performed with leſs fire, and in leſs time. He purifies and moulds his Phoſphorus much in the ſame manner as M. Hellot does. From the quantity of ingredients above-mentioned, he obtains two ounces and a half of fine cryſtalline moulded Phoſphorus.

M. Marggraff conſidering, as a conſequence of the experiments above related, that a highly concentrated Acid of Sea-ſalt contributes greatly towards the formation of Phoſphorus, proceeded to try ſeveral other experiments, in which he employed that Acid in a ſtate of combination with other baſes. He mixed, for inſtance, an ounce of *Luna cornea* with an ounce and half of putrefied and inſpiſſated urine, and from the mixture obtained a very beautiful Phoſphorus.

In ſhort, the ſeveral experiments mentioned having thoroughly perſuaded him that the Acid of Sea-ſalt, provided it were highly concentrated, would combine with the Phlogiſton as readily as the Vitriolic Acid does, he reſolved to try whether he could not make Phoſphorus with matters containing that Acid and the Phlogiſton, without making uſe of any urine.

With this view he made a great number of different trials, wherein he employed Sea-ſalt in ſubſtance, Sal Ammoniac, Plumbum corneum, Luna cornea, fixed Sal Ammoniac, otherwiſe called *Oil of Lime*. Theſe ſeveral ſubſtances, all of which contain the Acid of Sea-ſalt, he mixed with ſundry matters abounding in Phlogiſton, different vegetable coals, and even animal matters, ſuch as the oil of hartſhorn, human blood, &c. varying the proportions of theſe ſubſtances many different ways, without ever being able to produce a ſingle atom of Phoſphorus: which gave this able Chymiſt juſt cauſe to ſuſpect that the Marine Acid, while pure and crude, is not capable of combining with the Phlogiſton in the manner requiſite to form a Phoſphorus; that for this purpoſe it is neceſſary the Acid ſhould have contracted a previous union with ſome other matter; and that the Acid found in Urine hath probably undergone the neceſſary change. M. Marggraff is of opinion that the matter, which by its union renders the Marine Acid capable of entering into the compoſition of Phoſphorus, is a ſort of exceedingly ſubtile vitrifiable earth. The experiments he made upon the Acid of Phoſphorus will ſhew that his notion is not altogether groundleſs. M. Marggraff having let ſome urine, evaporated to the conſiſtence of honey, ſtand quiet in a cool place, obtained from it, by cryſtallization, a Salt of a ſingular nature. By diſtilling this urine afterwards, he ſatisfied himſelf that it yielded him much leſs Phoſphorus than urine from which no Salt had been extracted; and as it cannot be entirely deprived of this Salt, he thinks that the ſmall quantity of Phoſphorus which this urine yielded him came from the Salt that was ſtill left in it.

Further, he diſtilled this Salt ſeparately with lamp-black, and obtained from it a conſiderable quantity of very fine Phoſphorus. He even mixed *Luna cor-*

nea with this Salt, in order to ſee whether it would not increaſe the quantity of his Phoſphorus; but without ſucceſs: whence he concluded that in this Saline matter reſides the true Acid that is fit to enter into the compoſition of Phoſphorus. This opinion is confirmed by ſeveral experiments on the Acid of Phoſphorus, which he found to have ſome properties reſembling thoſe of this Salt.

The Acid of Phoſphorus ſeems to be more fixed than any other: and therefore if you would ſeparate it by burning from the Phlogiſton with which it is united, there is no occaſion for ſuch an apparatus of veſſels as is employed for obtaining the Spirit of Sulphur. For this Acid will remain at the bottom of the veſſel in which you burn your Phoſphorus: indeed, if it be urged by the force of fire, its moſt ſubtile part evaporates, and the remainder appears in the form of a vitrified matter.

This Acid efferveſces with fixed and volatile Alkalis, and therewith forms Neutral Salts; but very different from Sea-ſalt, and from Sal Ammoniac. That which has a fixed Alkali for its baſis does not crackle when thrown on burning coals; but ſwells and vitrifies like Borax. That which has a volatile Alkali for its baſis ſhoots into long pointed cryſtals; and, being urged by fire in a retort, lets go its volatile alkali, a vitrified matter remaining behind. This Salt is like that abovementioned, as obtained from urine and yielding Phoſphorus.

It appears from the experiments adduced, that the Acid of Phoſphorus tends always to vitrification; which proves that it is not pure, and gave M. Marggraff cauſe to think that it is altered by the admixture of a very ſubtile vitrifiable earth.

M. Marggraff alſo obtained Phoſphorus from ſeveral vegetable ſubſtances which we uſe every day for food. This gives him occaſion to conjecture that the Salt requiſite to the formation of Phoſphorus exiſts in vegetables, and paſſes from thence into the animals that feed upon them.

Laſtly, he concludes his diſſertation by informing us of a very important truth, viz. That the Acid obtained from Phoſphorus, by burning it, will ſerve to form Phoſphorus anew; for which purpoſe it need only be combined with ſome charred coal, ſuch as lamp-black, and diſtilled.

From what hath been ſaid on this ſubject it is plain the Chymiſts have a great many curious and intereſting enquiries to make concerning Phoſphorus, and particularly concerning its Acid.

I ſhall conclude this article with an account of certain properties of Phoſphorus which I have not yet mentioned.

Phoſphorus diſſolves by lying expoſed to the air. What water cannot effect, ſays M. Hellot, or at leaſt requires eight or ten years to bring about, the moiſture of the air accompliſhes in ten or twelve days; whether it be that the Phoſphorus takes fire in the air, and the inflammable part evaporating, almoſt entirely, leaves the Acid of the Phoſphorus naked, which like all other Acids, when exceedingly concentrated, is very greedy of moiſture; or elſe that the moiſture of the air, being water divided into infinitely fine particles, is ſo ſubtile as to find its way through the pores of the Phoſphorus, into which the groſſer particles of common water can by no means inſinuate themſelves.

Phoſphorus heated by the vicinity of fire, or by being any way rubbed, ſoon takes fire and burns fiercely. It is ſoluble in all Oils and in Ether, giving to thoſe liquors the property of appearing luminous, when the bottle containing the ſolution is opened. Being boiled in water, it likewiſe communicates thereto this luminous quality. M. Morin, Profeſſor at Chartres, is the author of this obſervation.

The late Mr. Groſſe, a celebrated Chymiſt, of the Academy of Sciences, obſerved that Phoſphorus being diſſolved in eſſential oils cryſtallizes therein. Theſe cryſtals take fire in the air, either when thrown into a dry veſſel, or wrapt up in a piece of paper. If they be dipped in Spirit of Wine, and taken out immediately, they do not afterwards take fire in the air: they ſmoke a little, and for a very ſhort time, but hardly waſte at all. Though ſome of them were left in a ſpoon for a fortnight, they did not ſeem to have loſt any thing of their bulk: but when the ſpoon was warmed a little they took fire, juſt like common Phoſphorus that had never been diſſolved and cryſtallized in an eſſential oil.

M. Marggraff, having put a dram of Phoſphorus with an ounce of highly concentrated Spirit of Nitre into a glaſs retort, obſerved that, without the help of fire, the Acid diſſolved the Phoſphorus; that part of the Acid came over into the recipient which was luted to the retort; that at the ſame time the Phoſphorus took fire, burnt furiouſly, and burſt the veſſels with exploſion. Nothing of this kind happens when any of the other Acids, though concentrated, are applied to Phoſphorus.

PROCESS III.

To decompoſe Sea-Salt by means of the Vitriolic Acid. Glauber's Salt. The Purification and Concentration of Spirit of Salt.

PUT the Sea-ſalt from which you mean to extract the Acid into an unglazed earthen pipkin, and ſet it amidſt live coals. The Salt will decrepitate, grow dry, and fall into a powder. Put this decrepitated Salt into a tubulated glaſs retort, leaving two thirds thereof empty. Set the retort in a reverberating furnace; apply a receiver like that uſed in diſtilling the ſmoking Spirit of Nitre, and lute it on in the ſame manner, or rather more exactly if poſſible. Then through the hole in the upper convexity of the retort pour a quantity of highly concentrated Oil of Vitriol, equal in weight to about a third part of your Salt, and immediately ſhut the hole very cloſe with a glaſs ſtopple, firſt rubbed therein with emery ſo as to fit it exactly.

As ſoon as the Oil of Vitriol touches the Salt, the retort and receiver will be filled with abundance of white vapours; and ſoon after, without lighting any fire in the furnace, drops of a yellow liquor will diſtill from the noſe of the retort. Let the diſtillation proceed in this manner without fire, as long as you perceive any drops come: afterwards kindle a very ſmall fire under the retort, and continue diſtilling and raiſing the fire by very ſlow degrees, and with great caution, to the end of the diſtillation; which will be finiſhed before you have occaſion to make the retort red-hot. Unlute the veſſels, and without delay pour the liquor, which is a very ſmoking Spirit of Salt, out of the receiver into a cryſtal bottle, like that directed for the ſmoking Spirit of Nitre.

OBSERVATIONS.

SEA-SALT, as hath been already ſaid, is a Neutral Salt compoſed of an Acid, which differs from thoſe of Vitriol and Nitre, combined with a Fixed Alkali that has ſome peculiar properties; but does not vary from the others in its affinities. This Salt therefore, as well as Nitre, muſt be decompoſed by the Vitriolic Acid; which accordingly is the caſe in the proceſs here deſcribed. The Vitriolic Acid unites with the Alkaline baſis of the Sea-ſalt, and ſeparates its Acid; and that with much greater facility than it expells the Nitrous Acid from its Alkaline baſis, becauſe the Acid of Sea-ſalt has not ſo great an affinity as the Nitrous Acid with Fixed Alkalis.

As a highly concentrated Oil of Vitriol is uſed on this occaſion, and as the Sea-ſalt is previouſly dried and decrepitated, the Acid obtained from it by diſtillation is very free from phlegm, and always ſmokes; even more violently than the ſtrongeſt Acid of Nitre. The vapours of this Acid are alſo much more elaſtic and more penetrating than thoſe of the Nitrous Acid: on which account this diſtillation of the ſmoking Spirit of Salt is one of the moſt difficult, moſt laborious, and moſt dangerous operations in Chymiſtry.

This proceſs requires a tubulated retort, that the Oil of Vitriol may be mixed with the Sea-ſalt after the receiver is well luted to the retort, and not before: for, as ſoon as theſe two matters come together, the Spirit of Salt ruſhes out with ſo much impetuoſity, that, if the veſſels were not luted at the time, the copious vapours that would iſſue through the neck of the ballon would ſo moiſten it, as well as the neck of the retort, that it would be impracticable to apply the lute and ſecure the joint as the operation requires. Moreover, the operator would be expoſed to thoſe dangerous fumes, which, on this occaſion, ruſh out and enter the lungs with ſuch incredible activity as to threaten inſtant ſuffocation.

Having ſaid ſo much of the elaſticity and activity of the fumes of Spirit of Salt, it is needleſs to inſiſt upon the neceſſity of giving vent to the veſſels from time to time, by opening the little hole of the ballon: indeed the beſt way to prevent the loſs of a great many vapours, on this occaſion, is to employ adopters, and cover them with wet canvas, which will cool and condenſe the vapours they contain.

When the operation is finiſhed, we find a white, ſaline maſs at the bottom of the retort as in a mould. If this maſs be diſſolved in water, and the ſolution cryſtallized, it yields a conſiderable quantity of Sea-ſalt that hath not been decompoſed, and a Neutral Salt conſiſting of the Vitriolic Acid united with the Alkaline baſis of that part which hath been decompoſed. This Neutral Salt, which bears the name of *Glauber* its inventor, differs from Vitriolated Tartar, or the *Sal de duobus*, which remains after diſtilling the Nitrous Acid, eſpecially in that it is more fuſible, more ſoluble in water, and hath its cryſtals differently figured. But as in theſe two Salts the Acid is the ſame, the differences that appear between them muſt be attributed to the peculiar nature of the baſis of Sea-ſalt.

Spirit of Salt drawn by the proceſs above deſcribed is tainted with a ſmall mixture of the Vitriolic Acid, carried up by the force of fire before it had time to combine with the Alkali of the Sea-ſalt; which happens likewiſe to the Nitrous Acid procured in the ſame manner. If you deſire to have it pure, and abſolutely free from the Acid of Vitriol, it muſt be diſtilled a ſecond time from Sea-ſalt, as the Acid of Nitre was before directed to be diſtilled again from freſh Nitre, in order to purify it from any Vitriolic taint.

Sea-ſalt, as well as Nitre, may be decompoſed by any combination of the Vitriolic Acid with a metallic or earthy ſubſtance: but it is proper to obſerve, that if you diſtill Spirit of Salt by means of Green Vitriol, the operation will not ſucceed ſo well as when Spirit of Nitre is diſtilled in the ſame manner: leſs Spirit is obtained, and a much fiercer fire is required.

The cauſe of this lies in the property which the Acid of Sea-ſalt poſſeſſes of diſſolving Iron, even when deprived of a part of its Phlogiſton by having contracted an union with another Acid; ſo that it is no ſooner diſlodged from its own baſis by the Vitriolic Acid, than it unites with the ferruginous baſis of the Vitriol, from which it cannot be ſeparated but by a moſt violent fire. This is the conſequence more eſpecially when calcined Vitriol is made uſe of: for moiſture, as we ſhall preſently ſee, greatly facilitates the ſeparation of the Marine Acid from thoſe ſubſtances with which it is united.

When you do not deſire a highly dephlegmated and ſmoking Spirit of Salt you may diſtill with the additament of any earth containing the Vitriolic Acid; as Clay, for inſtance, or Bole. To this end one part of Sea-ſalt, ſlightly dried and reduced to a fine powder, muſt be accurately mingled with two parts of the earth you intend to employ likewiſe pulverized; of this mixture make a ſtiff paſte with a proper quantity of rain water, and having formed little balls thereof about the ſize of a hazel nut, let them dry in the ſun; when dry put them into a ſtone or coated glaſs retort, leaving a third part thereof empty; ſet this veſſel in a reverberating furnace, covered with its dome; apply a receiver, which need not be luted on for ſome time; and heat the veſſels very ſlowly. At firſt an inſipid water will riſe; which muſt be thrown away: afterwards the Spirit of Salt will appear in white clouds. Now lute your veſſels, and raiſe the fire by degrees; which towards the end muſt be puſhed to the utmoſt extremity. The operation is known to be finiſhed when no drops fall from the noſe of the retort, the receiver cools, and the white vapours that filled it are ſeen no more.

The Spirit of Salt obtained by the proceſs here delivered does not ſmoke, and contains much more phlegm than that which is diſtilled by means of the concentrated Oil of Vitriol; becauſe the earth, though dried in the ſun, ſtill retains a great deal of moiſture, which commixes with the Acid of the Sea-ſalt. Conſequently it is much eaſier to collect its vapours; ſo that this operation is attended with much leſs trouble than the other. Nevertheleſs it is adviſeable to proceed gently; to apply but little heat at firſt, and to unſtop every now and then the ſmall hole of the receiver: for a quantity of the vapours of Spirit of Salt, even when weakened by the admixture of water, is very apt to burſt the veſſels.

A much greater degree of fire is neceſſary to raiſe the Spirit of Salt by this latter proceſs, than by that in which the pure Vitriolic Acid is employed: for, as faſt as the Spirit of Salt is diſlodged from its own baſis by the Vitriolic Acid contained in the earth made uſe of, part of it joins that earth, and cannot be ſeparated from it without the moſt violent heat.

A Spirit of Salt that ſhall not ſmoke may alſo be obtained by means of the pure Vitriolic Acid. Spirit of Vitriol, or Oil of Vitriol lowered with a good deal of water, will do the buſineſs.

Some Chymiſts direct a little water to be placed in the receiver, when Spirit of Salt is to be diſtilled by the intermedium of concentrated Oil of Vitriol, in order to make the acid vapours condenſe more readily. By this means indeed ſome of the inconveniences attending the diſtillation of ſmoking Spirit of Salt may be avoided: but on the other hand, the acid vapours being abſolutely ſuffocated by the water as faſt as they come over, the Spirit of Salt obtained by this method will be no leſs aqueous than that procured by the interpoſition of earths: ſo that here is an expence to no manner of purpoſe. Therefore, when a Spirit of Salt is deſired that ſhall not ſmoke, it is beſt to employ an additament of earth; and that ſo much the rather as the Marine Acid obtained by this means is purer and freer from any Vitriolic taint, for the reaſons already aſſigned.

Part of the Acid of Sea-ſalt may be ſeparated from its Alkaline baſis by the force of fire alone, without the intervention of any other body. With this view the Salt muſt be put into the retort without being dried. At firſt an inſipid water riſes; but it gradually becomes acid, and hath all the properties of Spirit of Salt. When the Salt in the retort is grown perfectly dry, nothing more can be forced over by any degree of heat whatever. If you would obtain more Acid from the ſame Salt, you muſt take it out of the retort, where you will find it in a lump, reduce it to powder, and expoſe it to the air for ſome time, that it may attract the moiſture thereof; or elſe wet it at once with ſome rain water, and diſtill as before. You will again have an inſipid water, and a little Spirit of Salt; which will in like manner ceaſe to riſe when the Salt in the retort becomes dry. This operation may be repeated as often as ſhall be thought proper: and perhaps it may be poſſible to decompoſe Sea-ſalt entirely by means thereof, without the interpoſition of any other body. The Spirit of Salt thus obtained is exceeding weak, in ſmall quantity, and loaded with much water.

This experiment proves that moiſture greatly facilitates the ſeparation of the Acid of Sea-ſalt from the matters with which it is united: and this is the reaſon that, in diſtilling of Spirit of Salt with the additament of an earth, the operation requires much leſs fire at the beginning, while the earth and ſalt retain a great deal of humidity, than towards the end, when they begin to grow dry.

After the operation there remains in the retort a ſaline and earthy maſs, which contains, 1. Some entire Sea-ſalt that has ſuffered no decompoſition; 2. A Glauber's Salt which is, as we ſaid before, a Neutral Salt conſiſting of the Vitriolic Acid united with the Alkaline baſis of the Sea-ſalt, from which it hath expelled its proper Acid; 3. Part of the earth uſed as an intermedium, ſtill retaining a portion of its original Vitriolic Acid, which, happening not to lie near enough to any particles of Sea-ſalt, could not exert its power in decompoſing them, and ſo remains united with its earthy baſis; 4. Another part of the ſame earth, impregnated with ſome of the Marine Acid, which combined therewith upon being expelled from its Alkaline baſis by the Vitriolic Acid, and which the force of fire was unable to ſeparate from it when the matters were grown perfectly dry. In conſequence of what remains in this *caput mortuum*, if the whole maſs be triturated, moiſtened with a little water, and diſtilled a ſecond time, conſiderably more Spirit of Salt will be obtained from it: and the ſame is to be ſaid of all diſtillations of this ſort.

Spirit of Salt obtained by the means of any other additament than concentrated Oil of Vitriol is generally very weak: but it may be dephlegmated and concentrated, if required, much in the ſame manner as Oil of Vitriol. For this purpoſe you muſt put it into a glaſs cucurbit, ſet it in a *balneum mariæ*, fit thereto a head and a receiver, and with a moderate degree of heat draw off one third or one half of the liquor. What comes over into the receiver will be the moſt aqueous part, which being the lighteſt will riſe firſt, impregnated however with a little acid: in the cucurbit will be left a concentrated Spirit of Salt, or the moſt acid part, which being the heavieſt will not riſe with the degree of heat that is capable of carrying up the phlegm. Spirit of Salt thus concentrated, called alſo *Oil of Salt*, does not ſmoke: it is of a yellow colour inclining to green, and an agreeable ſmell not unlike that of ſaffron.

PROCESS IV.

To decompoſe Sea-ſalt by means of the Nitrous Acid. Aqua regis. *Quadrangular Nitre.*

TAKE dried Sea-ſalt: bruiſe it to powder: put it into a glaſs retort, leaving one half of the veſſel empty. Pour upon it a third of its weight of good Spirit of Nitre. Place your retort in the ſand-bath of a reverberating furnace; put on the dome; lute to the retort a receiver having a ſmall hole in it, and heat the veſſels very ſlowly. There will come over into the receiver ſome vapours, and an acid liquor. Increaſe the fire gradually till nothing more riſes. Then unlute the veſſels, and pour the liquor out of the receiver into a cryſtal bottle, ſtopped like others containing Acid Spirits.

OBSERVATIONS.

THE Nitrous Acid hath a greater affinity than the Marine Acid with Fixed Alkalis. When therefore Spirit of Nitre and Sea-ſalt are mixed together, the ſame conſequences, in ſome meaſure, will follow, as when the Vitriolic Acid is mixed with that Salt; that is, the Nitrous Acid will, like the Vitriolic, decompoſe it, by diſlodging its Acid from its Alkaline baſis, and aſſuming its place. But as the Nitrous Acid is conſiderably weaker, and much lighter, than the Vitriolic Acid; a good deal of it riſes along with the Acid of Sea-ſalt during the operation. The liquor found in the receiver is therefore a true *Aqua regis.*

If decrepitated Salt, and a right ſmoking Spirit of Nitre, be employed in this proceſs, the *Aqua regis* obtained will be very ſtrong; and during the operation very elaſtic vapours will ruſh out and burſt the veſſels, if thoſe precautions be not taken which we pointed out as neceſſary in diſtilling the Spirit of Nitre, and the ſmoking Spirit of Salt.

The operation being finiſhed, there is left in the retort a ſaline maſs, containing Sea-ſalt not decompoſed, and a new ſpecies of Nitre, which having for its baſis the Alkali of Sea-ſalt, that is, as we have ſeveral times obſerved, an Alkali of a peculiar nature, differs from the common Nitre, 1. In the figure of its cryſtals; which are ſolids of four ſides, formed like lozenges; 2. In that it cryſtallizes with more difficulty, retains more water in its cryſtals, attracts the moiſture of the air, and diſſolves in water with the ſame circumſtances as Sea-ſalt.

CHAP. IV.

Of BORAX.

PROCESS.

To decompoſe Borax by the means of Acids, and to ſeparate from it the Sedative Salt by ſublimation and by cryſtallization.

REDUCE to a fine powder the Borax from which you intend to extract the Sedative Salt. Put this powder into a wide-necked glaſs retort. Pour upon it an eighth part of its weight of common water, to moiſten the powder; and then add concentrated Oil of Vitriol, to the weight of ſomewhat more than a fourth part of the weight of the Borax. Set the retort in a reverberatory, make a moderate fire at firſt, and augment it gradually till the retort become red-hot.

A little phlegm will firſt come over, and then with the laſt moiſture that the heat expells the Sedative Salt will riſe; by which means ſome of it will be diſſolved in this laſt phlegm, and paſs therewith into the receiver; but moſt of it will adhere in the form of ſaline flowers to the fore-part of the neck of the retort, juſt where it is clear of the groove of the furnace. There they collect into a heap, which the ſucceeding flowers puſh inſenſibly forward till they ſlightly ſtop the paſſage. Thoſe which riſe after the neck is thus ſtopped ſtick to the after-part of it which is hot, vitrify in ſome meaſure, and form a circle of fuſed Salt. In this ſtate the flowers of the Sedative Salt ſeem to iſſue out of the circle, as from their baſis: they appear like very thin, light, ſhining ſcales, and muſt be bruſhed off with a feather.

At the bottom of the retort will be left a ſaline maſs: diſſolve this in a ſufficient quantity of hot water; filter the ſolution in order to free it from a brown earth which it depoſites; ſet the liquor to evaporate, and cryſtals of Sedative Salt will form in it.

OBSERVATIONS.

THOUGH Borax is of great uſe in many chymical operations, eſpecially in the fuſion of metals, as we ſhall have occaſion to ſee, yet till of late years Chymiſts were quite ignorant of its nature, as they ſtill are of its origin; concerning which we know nothing with certainty, but that it comes rough from the Eaſt Indies, and is purified by the Dutch.

M. Homberg was one of the firſt that attempted to analyſe this Salt. He ſhewed that mixing it with the Vitriolic Acid, and diſtilling the mixture, a ſalt ſublimes in little fine needles. This product of Borax he called by the name of *Sedative Salt*, becauſe he found it had the property of moderating the great tumult and heat of the blood in fevers.

After M. Homberg other Chymiſts alſo exerciſed themſelves on Borax. M. Lemery diſcovered that the Vitriolic is not the only Acid by means of which the Sedative Salt may be obtained from Borax; but that either of the other two Mineral Acids, the Nitrous or the Marine, may be uſed in its ſtead.

M. Geoffroy hath greatly facilitated the means of obtaining the Sedative Salt from Borax; having ſhewn that it may be extracted by cryſtallization as well as by ſublimation; and that the Sedative Salt ſo obtained is in no reſpect inferiour to that whi was procured before by ſublimation only. T him alſo we are indebted for the diſcovery that i the compoſition of Borax there is an Alkaline Sa of the ſame nature as the baſis of Sea-ſalt. This h found by obſerving that he got a Glauber's Salt from a ſolution of Borax into which he had poured ſome Vitriolic Acid with a view to obtain its Sedative Salt.

Laſtly, M. Baron, whom we mentioned before on occaſion of this Salt, hath proved, by a great number of experiments, that a Sedative Salt may be procured from Borax by the help of Vegetable Acids, which was never done by any body before him; *that* the Sedative Salt is not a combination of an *Alkaline* matter with the Acid made uſe of in extracting it, as ſome of its properties ſeemed to indicate; *but* that it exiſts previouſly and completely formed *in the* Borax; that the Acid employed to extract it only helps to diſengage it from the Alkali with which it is united; that this Alkali is actually of the ſame nature as the baſis of Sea-ſalt, becauſe that after extracting the Sedative Salt, which by its union therewith forms the Borax, a Neutral Salt is found, of the ſame ſort with that which would be produced by combining the baſis of Sea-ſalt with the particular Acid made uſe of; that is, if with the Vitriolic Acid, a Glauber's ſalt; if with the Nitrous Acid, a quadrangular Nitre; and if with the Marine Acid, a true Sea-ſalt; and laſtly, that the Sedative Salt may be re-united to its Alkali, and re-produce a Borax.

Nothing therefore now remains, to give us all the inſight we can deſire into the nature of Borax, but to know what the Sedative Salt is. M. Baron hath already given us certain negative notices concerning it, by ſhewing what it is not; that is, that the Acid employed in its extraction doth not enter into its compoſition. We have great reaſon to hope that he will carry his enquiries ſtill further, and clear up all our doubts on this ſubject.

The Sedative Salt may be extracted from Borax, not only by the means of pure and ſimple Acids, but alſo by the ſame Acids combined with a metallic baſis. Thus Vitriols, for inſtance, may be employed for this purpoſe with good ſucceſs. It is eaſy to ſee that the Vitriol muſt be decompoſed on this occaſion, and that its Acid cannot unite with the Alkali in which the Sedative Salt is lodged, without quitting its metallic baſis, which muſt of courſe precipitate.

The Sedative Salt actually ſublimes, when a liquid containing it is diſtilled; but it does not therefore follow that it is naturally volatile. It riſes only by the aid of the water with which it is mixed. The proof of this aſſertion is, that, when all the humidity of the mixture containing this Salt is diſſipated, no more Salt will riſe, be the fire ever ſo violent; and that by adding more water to moiſten the dried maſs containing it, more Salt will every time be obtained, through many repeated diſtillations. In the ſame manner, if ſome Sedative Salt be moiſtened, and expoſed to a proper degree of heat, a ſmall quantity thereof will riſe at firſt by the help of the water; but as ſoon as it grows dry it remains exceedingly fixed. This obſervation we owe to M. Rouelle.

The Sedative Salt hath the appearance and the taſte of a Neutral Salt: it does not change the colour of the juice of violets; nor does it eaſily diſſolve in water; for it requires a quart of boiling water to diſſolve two ounces of it: yet, with regard to Alkalis, it has the properties of an Acid; it unites with thoſe ſalts, forms therewith a ſaline compound which cryſtallizes, and even expells the Acids that happen to be combined with them; ſo that it decompoſes the ſame Neutral Salts that are decompoſed by the Vitriolic Acid.

The Sedative Salt, when ſuddenly expoſed to the violent heat of a naked fire, loſes near half its weight, melts, puts on and retains the appearance of *glaſs*; but its nature ſtill remains unchanged. This glaſs diſſolves in water, and ſhoots anew into *cryſtals* of Sedative Salt. This Salt communicates to the Alkaline ſalt with which it is united, when in the form of Borax, the property of melting with a moderate heat, and forming a kind of glaſs; and 'tis this great fuſibility that recommends the frequent uſe of Borax as a flux for aſſaying ores. It is alſo employed ſometimes as an ingredient in the compoſition of glaſs; but, in time, it always communicates thereto the fault which its own glaſs hath, namely that of tarniſhing with the air. The Sedative Salt hath moreover the ſingular property of diſſolving in Spirit of Wine, and of giving to its flame, when ſet on *fire*, a beautiful green colour. All theſe obſervations we owe to Meſſ. Geoffroy and Baron.

M. Geoffroy prepares the Sedative Salt by cryſtallization only in the following manner. " He diſſolves four ounces of refined Borax in a ſufficient " quantity of warm water, and then pours into the " ſolution one ounce and two drams of highly con- " centrated Oil of Vitriol, which makes a crackling " noiſe as it falls in. When this mixture has ſtood " evaporating for ſome time, the Sedative Salt be- " gins to make its appearance in little, fine, ſhining " plates, floating on the ſurface of the liquor. The " evaporation is then to be ſtopped, and the plates " will by little and little encreaſe in thickneſs and " breadth. They unite together into little tufts, " forming with each other ſundry different groups. " If the veſſel be ever ſo little ſtirred, the regularity " of the cryſtals will be diſturbed; ſo that it muſt " not be touched till the cryſtallization appears to be " finiſhed. The cryſtalline cluſters, being grown " too bulky and too heavy, will then fall of them-

" ſelves to the bottom of the veſſel. This being ob-
" ſerved, the ſaline liquor muſt be gently decanted
" from thoſe little cryſtals, which, as they are not ea-
" ſily diſſolved, muſt be waſhed clean, by pouring
" cold water ſlowly on the ſides of the pan, three or
" four times ſucceſſively, in order to rinſe out all re-
" mains of the ſaline liquor, and then ſet firſt to drain,
" and afterwards to dry in the ſun. This Salt, in the
" form of light flakes of ſnow, is now ſoft to the
" touch, cool in the mouth, ſlightly bitter, crackling
" a little between the teeth, and leaving a ſmall im-
" preſſion of acidity on the tongue. It will keep long
" without giving or calcining, if managed accord-
" ing to the preceding directions; that is, if it be
" exactly freed from its ſaline liquor.

" It differs from the Sedative Salt obtained by
" ſublimation in this reſpect only, that notwith-
" ſtanding its ſeeming lightneſs it is a little heavier
" than the other. M. Geoffroy ſuppoſes the cauſe
" of this weight to be, that, as ſeveral of the thin
" plates adhere together in cryſtallizing, they retain
" between them ſome ſmall matter of humidity; or,
" if you will, that, as they form larger cryſtals, they
" preſent leſs ſurface to the air which elevates light
" bodies: whereas, on the contrary, the other Se-
" dative Salt, being driven up by the force of fire,
" riſes into the head of the cucurbit in a more ſubtile
" form, having its particles much more expanded
" and divided.

" M. Geoffroy, having put his Sedative Salt made
" by cryſtallization to all the ſame trials with that
" made by ſublimation, ſatisfied himſelf that there
" is no other difference between the two. If the
" Sedative Salt made by cryſtallization happens to
" calcine in the ſun; that is, if its luſtre tarniſhes,
" and its ſurface grows mealy, 'tis a ſign that it ſtill
" contains either a little Borax or ſome Glauber's
" Salt: for theſe two Salts are apt to calcine in this

“ manner, and pure Sedative Salt ſhould not be ſubject
“ to this inconvenience. In order to purify it,
“ and free it entirely from thoſe Salts, it muſt be
“ diſſolved once more in boiling water. As ſoon as
“ the water cools, the Sedative Salt re-appears in
“ light, ſhining, cryſtalline plates, ſwimming in the
“ liquor. After ſtanding four and twenty hours, the
“ liquor muſt be decanted, and the ſalt waſhed with
“ freſh water; by which means it will be very pure
“ and beautiful.”

Glauber's Salt and Borax diſſolve in water with vaſtly more eaſe than the Sedative Salt, and conſequently do not cryſtallize ſo readily by much: ſo that the ſmall portion of thoſe ſalts, which may have been left on the ſurface of the Sedative Salt, being diffuſed through a large quantity of water, continues in a ſtate of ſolution, while the Sedative *Salt* cryſtallizes; which being alſo waſhed afterwards with fair water, it is impoſſible that the ſmalleſt particle of thoſe other Salts ſhould remain adhering to it; and conſequently this muſt be deemed an excellent way of purifying it.

SECTION II.

Of Operations on METALS.

CHAP. I.

Of GOLD.

PROCESS I.

To ſeparate Gold, by Amalgamation with Mercury, from the Earths and Stones with which it is found mixed.

PULVERIZE the earths and ſtones containing Gold. Put the powder into a little wooden tray; dip this tray in water, gently ſhaking it and its contents. The water will grow muddy, by taking up the earthy parts of the ore. Continue waſhing it in this manner till the water ceaſe to appear turbid. Upon the ore thus waſhed pour ſtrong vinegar, having firſt diſſolved therein, by the help of heat, about a tenth part of its weight of alum. The powder muſt be quite drenched and covered with this liquor, and ſo left to ſtand for twice twenty four hours.

Decant the vinegar, and waſh your powder with warm water, till the laſt that comes off hath no taſte: then dry it, and put it into an iron mortar, with four times its weight of Quick-ſilver: triturate the whole with a heavy wooden peſtle, till all the powder be of a blackiſh colour: then pour in a little water, and continue rubbing for ſome time longer. More earthy and heterogeneous particles will be ſeparated from the metalline parts by means of this water, which will look dirty: it muſt then be decanted, and more fair water added. Repeat this ſeveral times; then dry what remains in the mortar with a ſponge, and by the help of a gentle heat; you will find it an Amalgam of the Mercury with the Gold.

Put this Amalgam into a chamoy bag: tie a knot on its neck, and ſqueeze it hard between your fingers, over ſome wide-mouthed veſſel; there will iſſue through the pores of the leather numberleſs little jets of Mercury, forming a ſort of ſhower, that will collect into large globules in the veſſel placed underneath. When you can force out no more Mercury by this means, open the bag, and in it you will find the Amalgam freed from the ſuperfluous Mercury; the Gold retaining only about as much thereof as nearly equals itſelf in weight.

Put this Amalgam into a glaſs retort: ſet this retort in the ſand bath of a reverberating furnace; cover it quite over with ſand; apply a glaſs receiver half full of water, ſo that the noſe of the retort may be under the water. The receiver need not be luted to the retort. Give a gradual heat, and raiſe the fire till drops of the ſublimed Mercury appear in the neck of the retort, and fall into the water with a hiſſing noiſe. If you hear any noiſe in the retort, ſlacken your fire a little. Laſtly, when you obſerve that, though you raiſe the fire ſtill higher than before, nothing more will come over; take out your retort, break it, and there you will find the Gold, which muſt be melted in a crucible with Borax.

OBSERVATIONS.

Gold is a perfect metal, which can by no means be deprived of its Phlogiſton, and on which few, even of the moſt powerful chymical ſolvents, have any effect: and therefore it almoſt always hath its metalline form when found in the earth; from which it may ſometimes be ſeparated by ſimple lotion.

The Gold duſt found in the ſands of certain rivers is of this kind. When it reſides in ſtones, or tenacious earths, it may be extracted by the proceſs here delivered; to wit, by Amalgamation or combination of Mercury with the Gold. Mercury is incapable of uniting with any earthy ſubſtances, not even with the metallic earths, when they are deprived of their Phlogiſton and conſequently have not the metalline form.

Hence it follows that when Mercury is triturated with particles of Gold, of earth, and of ſtone, mingled together, it unites with the Gold, and ſeparates it from thoſe heterogeneous matters. Yet, if there be along with the Gold any other metal, in its metalline form, except Iron, the Mercury will amalgamate with that alſo. This often happens to Silver, which being a perfect metal, as well as Gold, is for that reaſon ſometimes dug up in its metalline form, and even incorporated with Gold. When this is the caſe, the maſs that remains in the retort, after abſtracting the Mercury of the Amalgama, is a compound of Gold and Silver, which are to be ſeparated from each other by the methods we ſhall give for that purpoſe. The preſent proceſs is therefore applicable to Silver as well as Gold.

Sometimes Gold is intimately combined with ſuch mineral matters as hinder the Mercury from acting upon it. In that caſe the mixed maſs muſt be roaſted before you proceed to Amalgamation: for if the matters be volatile, ſuch, for inſtance, as antimony or arſenic, the fire will carry them off; ſo that after roaſting the Amalgamation will ſucceed. But ſometimes theſe matters are fixed, and require fuſion; if ſo, recourſe muſt be had to ſome particular methods, which we ſhall deſcribe when we come to treat of Silver, as theſe two perfect metals are to be treated in the ſame manner.

Ores containing Gold muſt be waſhed before an Amalgam is attempted; that the metalline parts, being freed from the numerous particles of earth with which they are encompaſſed, may the more readily incorporate with the Mercury. Beſides, it is the property of Mercury to take the form of a dark unmetallic powder, after being long rubbed with other matters, ſo that it cannot be eaſily diſtinguiſhed from the particles of earth. And hence, if you ſtill continue to grind the matters together after the Amalgamation is completed, and waſh them again and again, the water that comes off will always look turbid, being impregnated with ſome particles of the Amalgam. This is eaſily proved: for if you let the turbid water ſettle, and diſtill the ſediment, you will obtain Quick-ſilver from it.

The ore is to be ſteeped in vinegar charged with alum, in order to cleanſe the ſurface of the Gold, which is often covered with a thin coat of earth that obſtructs the Amalgamation.

Great care muſt be taken that the Mercury employed in this operation be very pure. If it be adulterated with any metallic ſubſtance, it muſt be freed therefrom by the methods which we ſhall propoſe in their proper place.

The way of ſeparating Mercury from Gold is founded on the different properties of theſe two metallic ſubſtances; the one being exceedingly fixed, and the other very volatile. The union which Mercury contracts with the metals is not intimate enough to give the new compound which reſults therefrom all the properties of either of the two united ſubſtances; at leaſt ſo far as concerns their degrees of fixity and volatility. Hence it comes that in our Amalgam the Gold communicates but very little of its fixity to the Mercury, and the Mercury communicates to the Gold but very little of its volatility. Yet if the Mercury be diſtilled off with a much greater degree of heat than is neceſſary to elevate it, a pretty conſiderable quantity of Gold will moſt certainly be carried up along with it.

It is alſo of conſequence, on another account, that the fire be duly governed on this occaſion. For if too great a degree of heat be applied, and the fire afterwards lowered, the water in the receiver, which covers the noſe of the retort, will riſe into its body, break it to pieces, and ſpoil the operation.

The cauſe of this phenomenon depends on the property which air poſſeſſes of rarefying with heat and condenſing with cold, joined to its weight. As ſoon as the retort is acted on by a leſs degree of heat than acted on it the inſtant before, the air contained therein is condenſed, and leaves a *vacuum*, which the external air, by virtue of its weight, tends to occupy; but, the orifice of the retort being under water, the external air can no way gain admittance, but by puſhing in before it the water which intercepts its paſſage. This caution, as we obſerved above, muſt be applied to all diſtillations where the veſſels are diſpoſed as they are in this.

Care muſt alſo be taken that the noſe of the retort be not placed too deep under water: for as the neck grows very warm during the operation, becauſe the degree of heat required to raiſe Mercury is about three times greater than that which raiſes water, it may eaſily be broken by the contact of the cold water in the receiver.

This method of extracting Gold and Silver from their ores, by Amalgamation with Mercury, is not to be abſolutely depended on as a ſure proof of the quantity of thoſe metals that may be contained in the earth aſſayed by this means: for ſome ſmall part of the Amalgam is always loſt in waſhing it; and moreover, the Mercury, when ſqueezed through chamoy, always carries with it a ſmall portion of Gold. So that if you deſire to know more exactly, by this method, the quantity of Gold or Silver contained in any earth, the Amalgam muſt not be ſqueezed through chamoy, but diſtilled altogether. Much the ſureſt method of making an accurate aſſay is that by fuſion and ſcorification, which we ſhall deſcribe under the head of Silver.

In ſome countries, and eſpecially in America, the method of Amalgamation is uſed for extracting Gold and Silver in large quantities from the matrices which contain them in their metalline form. Agricola and other metallurgiſts have deſcribed the machines by means whereof ſuch Amalgamations are managed.

PROCESS II.

To diſſolve Gold in Aqua regis, *and by that means to ſeparate it from Silver.* Aurum Fulminans. Aurum Fulminans *reduced.*

TAKE Gold that is perfectly pure, or alloyed with Silver only. Reduce it to little thin plates, by hammering it on an anvil. If it be not ſufficiently tough, neal it till it be red in a moderate, clear fire, quite free from ſmoking coals, and then let it cool gradually, which will reſtore its ductility.

When the plates are thin enough, make them red hot once more, and cut them into ſmall bits with a pair of ſheers. Put theſe bits into a tall, narrow-mouthed cucurbit, and pour on them twice their weight of good *Aqua regis*, made of one part Sal Ammoniac, or Spirit of Salt, and four parts Spirit of Nitre. Set the cucurbit in a ſand-bath moderately heated, ſtopping its orifice ſlightly with a paper coffin, to prevent any dirt from falling in. The *Aqua regis* will preſently begin to ſmoke. Round the little bits of Gold will be formed an infinite number of ſmall bubbles, which will riſe to the ſurface of the liquor. The Gold will totally diſſolve, if it be pure, and the ſolution will be of a beautiful yellow colour: if the Gold be alloyed with a ſmall quantity of Silver, the latter will remain at the bottom of the veſſel in the form of a white powder. If the Gold be alloyed with much Silver, when the Gold is diſſolved the Silver will retain the form of the little metalline plates put into the veſſel.

When the diſſolution is completed, gently pour off the liquor into another low, wide-mouthed, glaſs cucurbit, taking care that none of the Silver, which lies at the bottom in the form of a powder, eſcape with the liquor. On this powder of Silver pour as much freſh *Aqua regis* as will cover it entirely; and repeat this till you are ſure that nothing more can be taken up by it. Laſtly, having decanted the *Aqua regis* from the Silver, waſh the Silver with a little Spirit of Salt weakened with water, and add this Spirit of Salt to the *Aqua regis* in which your Gold is diſſolved. Then to the body containing theſe liquors fit a head and a receiver, and diſtill with a gentle heat, till the matter contained in the cucurbit become dry.

OBSERVATIONS.

IT is certain that *Aqua regis* is the true ſolvent of Gold, and that it does not touch Silver: ſo that if the Gold diſſolved in it were alloyed with Silver, which is often the caſe, the two metals would by this means be pretty accurately ſeparated from each other. But if you deſire to obtain from this ſolution a Gold abſolutely pure, you muſt free it, before you diſſolve it, from every other metallic ſubſtance but Silver; becauſe *Aqua regis* acts upon moſt of the other metals and the ſemi-metals. We ſhall ſhew under the head of Silver, as we promiſed before, how to purify a maſs of Gold and Silver from every other metallic alloy. Thither alſo we refer the common Parting Aſſay performed by means of *Aqua fortis*: becauſe in that operation the Silver is diſſolved, and not the Gold.

If the Gold put to diſſolve in *Aqua regis* be pure, the diſſolution is eaſily and readily effected. But if, on the contray, it be alloyed with Silver, the *Aqua regis* finds more difficulty in diſſolving it. Nay, if the Silver exceed the Gold in quantity, the diſſolution will not take place at all, for the reaſons adduced in our Theoretical Elements; of which we ſhall ſpeak more fully when we come to treat of the Parting Aſſay.

In the proceſs we directed the Gold to be diſſolved in a tall body. This precaution is neceſſary to prevent the loſs of ſome part thereof: for it is the property of *Aqua regis* to carry off along with it ſome of the Gold, eſpecially if there be any Sal Ammoniac in its compoſition, if the veſſel be heated while the diſſolution is going on, or if the *Aqua regis* be very ſtrong. Yet it is proper to make uſe of *Aqua regis* that is too ſtrong rather than too weak: for if it prove too ſtrong, and be obſerved not to act upon the metal for that reaſon, it is eaſy to weaken it, by gradually adding ſmall quantities of pure water, till you perceive it begin to act with vigour. This is a general rule regarding all metallic diſſolutions in Acids.

When the ſolution of Gold is evaporated to dryneſs, if you deſire to reduce into a maſs the Gold duſt left at the bottom of the cucurbit, you muſt put it into a crucible, and cover it with pulverized borax, mixed with a little nitre and calcined wine-lees; then cover the crucible cloſe, heat it with a moderate fire, which muſt be afterwards increaſed ſo as to melt the contents. At the bottom of the crucible you will find a lump of Gold, over which the ſalts you added will be as it were vitrified. Theſe ſalts are added chiefly to promote the fuſion of the metal.

The Gold may, if you will, be ſeparated from its ſolvent without evaporating the ſolution as above directed. You need only mix with the ſolution a fixed or volatile Alkali by little and little, till you ſee no more precipitate fall, and then let the liquor ſtand to ſettle, at the bottom of which you will find a ſediment: filter the whole, and dry what is left on the filter.

Both fixed and volatile Alkalis poſſeſſing, as hath been frequently repeated, a greater affinity with Acids than metallic ſubſtances have, they precipitate the Gold, and ſeparate it from the Acids in which it is diſſolved: but it is of great conſequence to take notice that, if you attempt to melt this precipitated Gold in a crucible, it will fulminate as ſoon as it feels the heat, with ſuch a terrible exploſion, that, if the quantity be at all conſiderable, it may prove fatal to the operator: even rubbing it a little hard will make it blow up. This preparation is therefore called *Aurum Fulminans*.

Hitherto no ſatisfactory explanation hath been given of this phenomenon. Some Chymiſts conſidering that, in the precipitation of the Gold, a Nitre is regenerated by the union of the Alkali with the Nitrous Acid which enters into the compoſition of the *Aqua regis*, imagine that ſome of this regenerated Nitre, combining with the precipitated Gold, takes fire and detonates, either by means of ſome ſmall portion of Phlogiſton that may be contained in the Alkali, or by means of that which conſtitutes the Gold itſelf. But, in the firſt place, 'tis well known that Fixed Alkalis do not contain Phlogiſton enough to make Nitre detonate. Indeed, if a Volatile Alkali be employed in the precipitation, a Nitrous Ammoniacal Salt will be formed, containing Phlogiſton enough to be capable of detonating without the concourſe of any additional Phlogiſton: but this detonation of the Nitrous Ammoniacal Salt is not to be compared, as to the violence of its effects, with the fulmination of Gold. Beſides, we do not find that Gold precipitated by a Volatile Alkali explodes with greater force than that precipitated by a Fixed Alkali. As for the Gold, 'tis certain that it ſuffers no decompoſition at all by fulminating. When fulminated under a glaſs bell, in ſuch ſmall quantities as not to endanger the operator, the Gold is found ſcattered about under the bell in very fine particles, without having undergone any alteration.

Others have fancied this fulmination of the Gold to be nothing but the decrepitation of the Sea-ſalt that is regenerated, in the precipitation of the metal, by the Fixed Alkali uniting with the Acid of Sea-ſalt which makes part of the *Aqua regis.* But to this it may be ſaid, that Gold precipitated by a Volatile Alkali fulminates as violently as that precipitated by a Fixed Alkali; and yet no Sea-ſalt can be formed in the liquor by the addition of a Volatile Alkali, but only a Sal Ammoniac which has not the property of decrepitating. Moreover, there is no compariſon, as to the effects, between the decrepitation of Sea ſalt and the fulmination of Gold.

Nor, laſtly, can this fulmination be attributed, as it is by ſome, to the effort made by the Salts to eſcape from amidſt the particles of Gold, in which they are ſuppoſed by them to be impriſoned: for then we might deprive this Gold entirely of its fulminating quality by only boiling it in water, and ſo waſhing off all the ſaline particles, which probably adhere to its ſurface only. It is plain there is great room for very beautiful diſcoveries on this ſubject. In Walerius's Mineralogy we find ſome obſervations that may throw a little light on the point before us.

" The quantity, ſays he, of fulminating Gold " precipitated exceeds that of the Gold diſſolved : " if the *Aqua regis* be made with Sal Ammoniac the " exploſion will be ſtronger; it will alſo be more " violent if the ſolution be precipitated with a Vola- " tile Alkali, than if a Fixed Alkali be uſed for that " purpoſe."

One of the ſpeedieſt and eaſieſt methods to deprive this Gold of its fulminating quality, is to grind in a mortar twice as much flowers of Sulphur as you have Gold to reduce, mixing your fulminating Gold therewith by little and little as you grind them together; then to put the mixture into a crucible, and heat it juſt enough to melt the Sulphur. Part of the Sulphur will be diſſipated in vapours, and the reſt will burn away. When it is quite conſumed, encreaſe the fire ſo as to make the crucible red-hot. When you perceive no more ſmell of Sulphur, pour on the Gold a little Borax, previouſly melted in another crucible with a Fixed Alkali, as calcined Wine-lees, or Nitre fixed with Tartar; and then raiſe the fire ſufficiently to make the whole flow. After the fuſion is completed you will find a button of Gold at the bottom of the crucible under the ſalts.

Fulminating Gold may alſo be reduced by pouring on it a ſufficient quantity of Fixed Alkali reduced to a liquor, or of Oil of Vitriol, evaporating all the moiſture, and gradually throwing what remains, mixed up with ſome pinguious matter, into a crucible kept red-hot in a furnace. The reaſon why theſe ſubſtances deprive the Gold of its fulminating quality depends on the cauſes that produce the fulmination.

Gold may alſo be ſeparated from *Aqua regis*, and precipitated by the means of ſeveral metallic ſubſtances that have a greater affinity, either with *Aqua regis*, or with one of the two Acids that compoſe it. Mercury is one of the fitteſt for this purpoſe. On dropping a ſolution of Mercury in the Nitrous Acid by little and little into a ſolution of Gold, the mixture becomes turbid, and a precipitate is formed. Continue dropping in more of the ſolution of Mercury till no more precipitate falls; then let the liquor ſtand to ſettle, and at the bottom of it you will find a ſediment, which is the precipitated Gold: pour off the liquor by inclination, and waſh the precipitate with fair water.

Mercury hath a greater affinity with the Marine than with the Nitrous Acid. The affinity which Mercury hath with the Marine Acid is alſo greater than that of Gold with the Marine Acid; for unleſs this Acid be aſſociated either with the Nitrous Acid, or at leaſt with a certain proportion of Phlogiſton, it will not diſſolve Gold. Hence it comes that when a ſolution of Mercury in the Nitrous Acid is dropped into a ſolution of Gold in *Aqua regis*, the Mercury unites with the Acid of Sea-ſalt, which is an ingredient in the *Aqua regis:* but the Marine Acid cannot on this occaſion join the Mercury, without deſerting the Gold and the Nitrous Acid with which it was united; and then the Gold, which cannot be kept in ſolution by the Nitrous Acid alone, is forced to quit its ſolvent and precipitate The liquor therefore, that now floats over the Gold thus precipitated, muſt contain Mercury united with the Acid of Sea-ſalt; and in fact it yields a true Corroſive Sublimate, which is known to be a combination of Mercury with the Marine Acid.

Mercury diſſolved in Spirit of Nitre is employed to procure the precipitation we are ſpeaking of; becauſe metallic ſubſtances, when ſo comminuted by an Acid, are much fitter for ſuch experiments than when they are in a concrete form.

Gold precipitated in this manner by a metallic ſubſtance doth not fulminate.

PRO-

PROCESS III.

To diſſolve Gold by Liver of Sulphur.

MIX together equal parts of common Brimſtone, and a very ſtrong Fixed Alkali; for inſtance, Nitre fixed by charcoal. Put them in a crucible, and melt the mixture, ſtirring it from time to time with a ſmall rod. There is no occaſion to make the fire very briſk, becauſe the Sulphur facilitates the fuſion of the Fixed Alkali. Some ſulphureous vapours will riſe from the crucible: the two ſubſtances will mix intimately together, and form a reddiſh compound. Then throw into the crucible ſome little pieces of Gold beat into thin plates, ſo that the whole do not exceed in weight one third part of the Liver of Sulphur: raiſe the fire a little. As ſoon as the Liver of Sulphur is perfectly melted, it will begin to diſſolve the Gold with ebullition; and will even emit ſome flaſhes of fire. In the ſpace of a few minutes the Gold will be entirely diſſolved, eſpecially if it was cut and flatted into ſmall thin leaves.

OBSERVATIONS.

The proceſs here delivered is taken from M. Stahl. The deſign of that ingenious Chymiſt's enquiries was to diſcover how Moſes could burn the golden calf, which the Iſraelites had ſet up and worſhipped while he was on the mount; how he could afterwards reduce that calf to powder, throw it into the water which the people uſed, and make all who had apoſtatized drink thereof, as related in the Book of Exodus.

M. Stahl, having firſt obſerved that Gold is abſolutely inalterable and indeſtructible by the force of fire alone, be it ever ſo violent, concludes, that without a miracle Moſes could not poſſibly perform the above mentioned operations on the golden calf any way but by mixing with the Gold ſome matter qualified to alter and diſſolve it. He then takes notice that pure Sulphur does not act upon Gold at all, and that many other ſubſtances, which are thought capable of dividing and diſſolving it, cannot however do it ſo completely as is neceſſary to render that metal ſuſceptible of the effects related. He then gives the method of diſſolving it by Liver of Sulphur deſcribed in the proceſs.

Liver of Sulphur diſſolves likewiſe all the other metals: but M. Stahl obſerves that it attenuates Gold more than any other metallic ſubſtance, and unites with it much more intimately than with the reſt. This appears from what happens on attempting to diſſolve in water any of the mixts reſulting from the union of another metal with Liver of Sulphur: for then the metal ſeparates, and appears in the form of a powder or fine calx; whereas, when Gold is united with Liver of Sulphur, the whole compound diſſolves in water ſo perfectly, that the Gold even paſſes with the Liver of Sulphur through the pores of filtering paper.

If an Acid be poured into a ſolution of this combination of Gold with Liver of Sulphur, the Acid unites with the Alkali of the *Hepar*, and the Gold falls to the bottom of the liquor along with the Sulphur, which doth not quit it. The Sulphur thus precipitated with the Gold is eaſily carried off by a ſlight torrefaction, after which the Gold remains exceedingly comminuted. The Sulphur of this compound may alſo be deſtroyed by torrefaction, without the trouble of a previous ſolution and precipitation, and then alſo the Gold remains ſo attenuated as to be miſcible with liquors, and floats on them, or ſwims in them, in ſuch a manner that it may eaſily be ſwallowed with them in drinking. From all this M. Stahl concludes there is great reaſon to believe it was by means of the Liver of Sulphur that Moſes divided, and in a manner calcined, the golden calf, ſo that he could mingle it with water, and make the Iſraelites drink it.

PROCESS IV.

To ſeparate Gold from all other metallic Subſtances by means of Antimony.

HAVING put the Gold you intend to purify into a crucible, ſet it in a melting furnace, cover it, and make the Gold flow. When the metal is in fuſion caſt upon it, by a little at a time, twice its weight of pure crude Antimony in powder, and after each projection cover the crucible again immediately: this done keep the matter in fuſion for a few minutes. When you perceive that the metallic mixture is perfectly melted, and that its ſurface begins to ſparkle, pour it out into a hollow iron cone, previouſly heated, and ſmeared on the inſide with tallow. Immediately ſtrike with a hammer the floor on which the cone ſtands; and when all is cold, or at leaſt ſufficiently fixed, invert the cone and ſtrike it: the whole metallic maſs will fall out, and the under part thereof, which was at the point of the cone, will be a Regulus more or leſs yellow as the Gold was more or leſs pure. On ſtriking the metallic maſs the Regulus will freely part from the ſulphureous cruſt at top.

Return this Regulus into the crucible, and melt it. Leſs fire will do now than was required before. Add the ſame quantity of Antimony, and proceed as at firſt. Repeat the ſame operation a third time, if your Gold be very impure.

Then put your Regulus into a good crucible, much larger than is neceſſary to hold it. Set your crucible in a melting furnace, and heat the matter but juſt enough to make it flow, with a ſmooth, brilliant ſurface. When you find it thus conditioned, point towards it the noſe of a long-ſnouted pair of bellows, and therewith keep gently and conſtantly blowing. There will ariſe from the crucible a conſiderable ſmoke, which will abate greatly when you ceaſe to blow, and increaſe as ſoon as you begin again. You muſt raiſe the fire gradually as you approach towards the end of the operation. If the ſurface of the metal loſe its brilliant poliſh, and ſeem covered with a hard cruſt, 'tis a ſign the fire is too weak; in which caſe it muſt be increaſed, till the ſurface recover its ſhining appearance. At laſt, when no more ſmoke riſes, and the ſurface of the Gold looks neat and greeniſh, caſt on it, by little and little, ſome pulverized Nitre, or a mixture of Nitre and Borax. The matter will ſwell up. Continue thus adding more Nitre gradually, till no commotion is thereby produced in the crucible; and then let the whole cool. If you find, when the Gold is cold, that it is not tough enough, melt it over again; when it begins to melt caſt in the ſame Salts as before; and repeat this till it be perfectly ductile.

OBSERVATIONS.

ANTIMONY is a compound, conſiſting of a ſemimetallic part united with about a fourth part of its weight of common Sulphur. It appears, in the ninth column of the Table of Affinities, that all the metals, Mercury and Gold excepted, have a greater affinity than the reguline part of Antimony with Sulphur. If therefore Gold, adulterated with a mixture of Copper, Silver, or any other metal, be melted with Antimony, thoſe metals will unite with the Sulphur of the Antimony, and ſeparate it from the reguline part, which being thus ſet free will combine and be blended with the Gold. Theſe two metallic ſubſtances, forming a maſs far heavier than the other metals mixed with the ſulphur, fall together to the bottom of the crucible in the form of a Regulus, while the others float over them like a ſort of ſcoria or ſlag: and thus the Gold is freed from all alloy but the reguline part of the Antimony.

As all the other metals have a great affinity with Sulphur, and Gold is the only one that is capable of reſiſting its action, one would think Sulphur alone might be ſufficient to free it from the metals combined with it, and that it would therefore be better to employ pure Sulphur, in this operation, than to make uſe of Antimony; the reguline part of which remaining united with the Gold requires another long and laborious operation to get rid of it.

Indeed, ſtrictly ſpeaking, Sulphur alone would be ſufficient to produce the deſired ſeparation: but it is proper to obſerve that, as Sulphur alone is very combuſtible, moſt of it would be conſumed in the operation before it could have an opportunity to unite with the metallic ſubſtances; whereas when it is combined with the Regulus of Antimony, it is thereby enabled to bear the action of the fire much longer without burning, and conſequently is much fitter for the purpoſe in queſtion. Beſides, if we were to make uſe of pure Sulphur, a great part of the Gold, which is kept in perfect fuſion, and its precipitation facilitated, by the Regulus of Antimony, would remain confounded with the ſulphureous ſcoria.

Nevertheleſs, ſeeing the metals with which Gold is alloyed cannot be ſeparated from it by Antimony, but that a quantity of Regulus proportioned to the quantity of the metals ſo ſeparated will unite with the Gold, and that the more Regulus combines with the Gold, the more tedious, chargeable, and laborious will the operation prove, this conſideration ought to have ſome influence in directing our proceſs. Therefore, if the Gold be very impure, and worſe than ſixteen carats, we muſt not mix it with crude Antimony alone, but add two drams of pure Sulphur for every carat the Gold wants of ſixteen, and leſſen the quantity of Antimony in proportion to that of the real Gold.

It is neceſſary to keep the crucible cloſe covered, after mixing the Antimony with the Gold, to prevent any coals from falling into it: for, if that ſhould happen, the melted maſs would puff up conſiderably, and might perhaps run over.

The inſide of the cone, into which you pour the melted metallic maſs, muſt be greaſed with tallow, to prevent its ſticking thereto, and that it may come eaſily out. Striking the floor, on which the cone with the melted metal ſtands, helps the precipitation and deſcent of the Regulus of Gold and Antimony to the bottom of the cone.

Leſs fire is requiſite to melt this compound Regulus, in order to add freſh Antimony, than was neceſſary before the Gold was mixed with the reguline part of the Antimony; becauſe this metallic ſubſtance, being much more fuſible than Gold, promotes its melting. The Antimony is mixed with the Gold by repeated projections; that the ſeparation of the metals may be accompliſhed with the greater eaſe and accuracy. Yet the operation might be ſucceſsfully performed, by putting in all the Antimony at once, and with one melting only.

The metalline maſs found at the bottom of the cone after all theſe operations, is a mixture of Gold with the reguline part of the Antimony. All the reſt of the proceſs conſiſts only in ſeparating this reguline part from the Gold. As Gold is the moſt fixed of all metals, and as the Regulus of Antimony cannot bear the violence of fire without flying off in vapours, nothing more is neceſſary for this purpoſe but to expoſe the compound, as directed in the proceſs, to a heat ſtrong enough, and long enough continued, to diſſipate all the Regulus of Antimony. This ſemi-metal exhales in the form of a very thick white ſmoke. It is proper to blow gently into the crucible during the whole operation; becauſe the immediate contact of the freſh air inceſſantly thrown in promotes and conſiderably encreaſes the evaporation: and this is a general rule applicable to all evaporations.

The fire muſt be gradually raiſed as the Regulus of Antimony is diſſipated, and the operation draws toward an end; becauſe the mixed maſs of Regulus of Antimony and Gold becomes ſo much the leſs fuſible as the proportion of the Regulus is leſſened. Though the Regulus of Antimony be ſeparated from the Gold in this operation, becauſe the latter is of ſuch a fixed nature that it cannot be volatilized by the degree of fire which diſſipates the Regulus; yet, as the Regulus is very volatile, it will undoubtedly carry up ſome of the Gold along with it, eſpecially if you hurry on the evaporation too faſt, by applying too great a degree of fire, by blowing too briſkly into the crucible, and ſtill more if you evaporate your mixture in a broad flat veſſel inſtead of a crucible. All theſe things muſt therefore be avoided, if you would loſe no more Gold than you needs muſt.

However, unleſs the evaporation be carried to the utmoſt, by the means above pointed out, a ſmall portion of the Regulus of Antimony will always remain combined with the Gold, which defends it from the action of the fire. This ſmall portion of Regulus hinders the Gold from being perfectly pure and ductile. In order therefore to conſume and ſcorify it we caſt Nitre into the crucible when we perceive it to emit no more white vapours.

We know that Nitre has the property of reducing all metallic ſubſtances to a calx, Gold and Silver excepted; becauſe it deflagrates with the phlogiſton to which their metalline form is owing: but as this accenſion of the Nitre occaſions a tumid efferveſcence, care muſt be taken to throw it in but by little and little at a time; for if too much be projected at once the melted matter will run over.

This operation might be conſiderably abridged by taking advantage of the property which Nitre poſſeſſes of thus conſuming the phlogiſton of metallic ſubſtances; as by means thereof we might deſtroy all the Regulus of Antimony incorporated with the Gold, without having recourſe to a long and tedious evaporation. But then we ſhould at the ſame time loſe a much greater quantity of Gold, by reaſon of the tumult and ebullition which are inſeparable from the detonation of Nitre. On the whole therefore, if Nitre be made uſe of to purify Gold, great care muſt be taken to apply but very little of it at a time.

All the Silver that was mixed with the Gold, and indeed a little of the Gold itſelf, remains confounded with the ſulphureous ſcoria, which floats upon the Golden Regulus after the addition of the Antimony: we ſhall ſhew in the Chapter on Silver how theſe two metals are to be ſeparated from the Sulphur.

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CHAP. II.

Of SILVER.

PROCESS I.

To ſeparate Silver from its Ore, by means of Scorification with Lead.

BEAT to powder in an iron mortar the ore from which you mean to ſeparate the Silver, having firſt roaſted it well in order to free it from all the Sulphur and Arſenic that it may contain. Weigh it exactly: then weigh out by itſelf eight times as much granulated Lead. Put one half of this Lead into a teſt, and ſpread it equally thereon: upon this Lead lay your ore, and cover it quite over with the remaining half of the Lead.

Place the teſt thus loaded under the further end of the muffle in a cupelling furnace. Light your fire, and increaſe it by degrees. If you look through one of the apertures in the door of the furnace you will perceive the ore, covered with calcined Lead, ſwim upon the melted Lead. Preſently afterwards it will grow ſoft, melt, and be thrown towards the ſides of the veſſel, the ſurface of the Lead appearing in the midſt thereof bright and ſhining like a luminous diſc: the Lead will then begin to boil, and emit fumes. As ſoon as this happens the fire muſt be a little checked, ſo that the ebullition of the Lead may almoſt entirely ceaſe for about a quarter of an hour. After this it muſt be excited to the degree it was at before, ſo that the Lead may begin again to boil and ſmoke. Its ſhining ſurface will gradually leſſen, and be covered with *ſcoriæ*. Stir the whole with an iron hook, and draw in towards the middle what you obſerve towards the ſides of the veſſel; to the end that, if any part of the ore ſhould ſtill remain undiſſolved by the Lead, it may be mixed therewith.

When you perceive that the matter is in perfect fuſion, that the greateſt part of what ſticks to the iron hook, when you dip it in the melted matter, ſeparates from it again, and drops back into the veſſel; and that the extremity of this inſtrument when grown cold, appears varniſhed over with a thin, ſmooth, ſhining cruſt; you may look on theſe as marks that the buſineſs is done, and the more uniform and evenly the colour of the cruſt is, the more perfect may you judge the ſcorification to be.

Matters being brought to this paſs, take the teſt with a pair of tongs from under the muffle, and pour its whole contents into an iron cone, firſt heated and greaſed with tallow. This whole operation laſts about three quarters of an hour. When all is cold, the blow of a hammer will part the Regulus from the ſcoria; and as it is not poſſible, how perfect ſoever the ſcorification be, to avoid leaving a little Lead containing Silver in the ſcoria, it is proper to pulveriſe this ſcoria, and ſeparate therefrom whatever extends under the hammer, in order to add it to the Regulus.

OBSERVATIONS.

Silver, as well as Gold, is often found quite pure, and under its metalline form, in the bowels of the earth; and in that caſe it may be ſeparated from the ſtones or ſand, in which it is lodged, by ſimple waſhing, or by Amalgamation with Mercury, in the ſame manner as before directed for Gold. But it alſo happens frequently that Silver is combined in the ore with other metallic ſubſtances and minerals, which will not admit of this proceſs, but force us to employ other methods of ſeparating it from them.

Sulphur and Arſenic are the ſubſtances to which Silver and the other metals uſually owe their mineral ſtate. Theſe two matters are never very cloſely united with Silver; but may be pretty eaſily ſeparated from it by the action of fire, and the addition of Lead. If Arſenic be predominant in a Silver ore, it will unite with the Lead by the help of a pretty moderate heat, and quickly convert a conſiderable quantity thereof into a penetrating fuſible glaſs, which has the property of ſcorifying with eaſe all ſubſtances that are capable of ſcorification.

When Sulphur predominates, the ſcorification proceeds more ſlowly, and doth not always ſucceed; becauſe that mineral combined with Lead leſſens its fuſibility, and retards its vitrification. In this caſe part of the Sulphur muſt be diſſipated by roaſting: the other part unites with the Lead; and that, being rendered lighter by this union, floats on the reſt of the mixture, which chiefly contains the Silver. At laſt the joint action of the air and of the fire, diſſipates the portion of Sulphur that had united with the Lead: the Lead vitrifies and reduces to a ſcoria whatever is not either Silver or Gold: and thus the Silver being diſentangled from the heterogeneous matters with which it was united, one part thereof being diſſipated and the other vitrified, combines with the portion of Lead which is not vitrified, and falls through the ſcoria, which to favour its deſcent muſt be in perfect fuſion

The whole proceſs therefore conſiſts of three diſtinct operations. The firſt is Roaſting, which diſſipates ſome of the volatile ſubſtances found united with the Silver: the ſecond is Scorification, or the Vitrification of the fixed matters alſo united with the Silver, ſuch as ſand, ſtones, metals, &c. and the third is Precipitation, or the ſeparation of the Silver from the ſcoria. The two firſt are, as hath been ſhewn, preparatives for the laſt, and indeed produce it.

As every thing we ſaid concerning Gold, when we treated of the proceſs of Amalgamation, is to be applied to Silver, which may be extracted by the ſame method when it is in its metalline form; in the ſame manner all we now advance touching the method of extracting Silver by Scorification, when it is depraved with a mixture of heterogeneous matters, is equally applicable to Gold in the ſame circumſtances: and indeed Silver almoſt always contains more or leſs Gold naturally.

In the proceſs we directed that the ore ſhould be pulverized before it be expoſed to the fire, with a view to enlarge its ſurface, and by that means facilitate the action of the Lead upon it, as well as the evaporation of its volatile parts.

We recommended the precaution of ſlackening the fire a little at the beginning of the operation, only to prevent the Lead from being too haſtily converted into litharge, leſt it ſhould penetrate and corrode the teſt before it had wholly diſſolved the ore: but if we were perfectly certain of the veſſel's being ſo good as to be in no danger of penetration by the Lead, this precaution would be needleſs.

It is proper to add eight parts of Lead for one of ore; though ſo much is not always abſolutely neceſſary, eſpecially when the ore is very fuſible. The ſucceſs of this operation depends chiefly on the completeneſs of the Scorification; and therefore the addition of more Lead than enough is attended with no inconvenience: for, as it always promotes the ſcorification, it can never do any harm.

If the ore be mixed with ſuch earthy and ſtony parts as cannot be ſeparated from it by waſhing, it is the more difficult of fuſion, even though the ſtones ſhould be ſuch as are moſt diſpoſed to vitrify; becauſe the moſt fuſible earths and ſtones are always leſs ſo than moſt metallic ſubſtances. In that caſe it will be neceſſary, for effecting the Scorification, to mix thoroughly with the pulverized ore an equal quantity of Glaſs of Lead, to add twelve times as much granulated Lead, and then to proceed as directed for a fuſible ore; expoſing the mixture to a degree of fire ſtrong enough, and long enough kept up, to give the ſcoria all the properties above required as ſigns of a perfect ſcorification.

Silver ore is ſometimes mixed with pyrites, and the ore of Arſenic, or cobalt, which alſo make it refractory. As the pyrites contain a large quantity of Sulphur, which is very volatile as well as Arſenic; in this caſe it is proper to begin with freeing the ore from theſe two extraneous ſubſtances. This is eaſily done by roaſting: only be ſure, when you firſt expoſe the ore to the heat, to cover the veſſel in which you roaſt it, for ſome minutes, with an inverted veſſel of the ſame width; becauſe ſuch ſorts of ore are very apt to fly when they firſt feel the heat.

After this uncover it, and leave it expoſed to the fire till no more ſulphureous or arſenical matters riſe. Then mix it with the ſame quantity of Glaſs of Lead as we ordered for ores rendered refractory by the admixture of earths or ſtones, and proceed in the ſame manner.

It is the more neceſſary to roaſt Silver ore infected with Sulphur and Arſenic, becauſe, as Sulphur obſtructs the fuſion of Lead, it cannot but do hurt, and protract the operation; and Arſenic does miſchief, on the other hand, by ſcorifying a very great quantity of Lead too haſtily.

When the Sulphur and Arſenic are diſſipated by roaſting, the ore muſt be treated like that which is rendered refractory by ſtony and earthy matters; for as the pyrites contain much iron, there remains, after the Sulphur is evaporated, a conſiderable quantity of martial earth, which is difficult to ſcorify. The pyrites, as well as the cobalts, contain moreover an unmetallic earth, which is hard to fuſe.

The general rule therefore is, when the ore is rendered refractory by any cauſe whatever, to mix it with Glaſs of Lead, and to add a larger quantity of granulated Lead. Yet ſome ores are ſo refractory that Lead alone will not do the buſineſs, and recourſe muſt be had to ſome other flux. That which is fitteſt for the preſent purpoſe is the *Black Flux*, compoſed of one part of Nitre and two parts of Tartar deflagrated together. The Phlogiſton contained in this quantity of Tartar is more than ſufficient to alkalizate the Nitre. This Flux therefore is nothing more than Nitre alkalizated by Tartar, mixed with ſome of the ſame Tartar that hath not loſt its Phlogiſton, and is only reduced to a ſort of coal.

The *White Flux* is alſo very fit to promote fuſion; but on this occaſion the Black Flux is preferable, becauſe the Phlogiſton of the Black Flux prevents the Lead from being too ſoon converted to litharge, and ſo gives it time to diſſolve the metallic matters. The White Flux, which is the reſult of equal parts of Tartar and Nitre alkalizated together, being no more than an Alkali deſtitute of Phlogiſton, or containing but very little, doth not poſſeſs this advantage.

If Silver ſhould be combined in the ore with Iron in its metalline ſtate, which however does not commonly happen, then, in order to ſeparate them, the Iron muſt be deprived of its Phlogiſton, and converted to a *crocus* before the mixed maſs be melted with Lead; which may be done by diſſolving it in the Vitriolic Acid, and then evaporating the Acid.

We are neceſſitated to make uſe of this contrivance, becauſe Iron in its metalline form cannot be diſſolved either by Lead or by the Glaſs of Lead; but when it is reduced to a calx, litharge unites with it and ſcorifies it.

If you have not at hand the utenſils neceſſary for performing the operation we have been deſcribing in a teſt, a teſt, and under the muffle; or if you have a mind to work on a greater quantity of ore at a time, you may make uſe of a crucible for the purpoſe, and perform the operation in a melting furnace.

In this caſe the ore muſt be prepared, as above directed, according to its nature, and mixed with a proper quantity of Lead and Glaſs of Lead; the whole put into a good crucible, leaving two thirds thereof empty, and covered with a mixture of Sea-ſalt and a little Borax, both very dry, to the thickneſs of a full half inch.

This being done, ſet the crucible in the midſt of a melting furnace; raiſe the coals quite to the lip of the crucible; light the fire; cover the furnace with its dome; but do not urge the fire more than is neceſſary to bring the mixture to perfect fuſion: leave it thus in fuſion for a good quarter of an hour; ſtir the whole with a bit of ſtrong iron wire; then let it cool; break the crucible, and ſeparate the Regulus from the ſcoria.

The Salts added on this occaſion are fluxes, and their uſe is to procure a perfect fuſion of the ſcoria.

If the melted matters be left expoſed to the fire, either in a teſt, or in a crucible, longer than is above preſcribed, the portion of Lead that hath united and precipitated with the Silver will at laſt vitrify, and at the ſame time ſcorify all the alloy with which that metal may be mixed. But as there are no veſſels that can long endure the action of litharge, without being pierced like a ſieve, ſome of the Silver may eſcape through the holes or fiſſures of the veſſel, and ſo be loſt. It is better therefore to complete the purification of your Silver by the operation of the Cupel, the deſcription of which follows.

PROCESS II.

The refining of Silver by the Cupel.

TAKE a cupel capable of containing one third more matter than you have to put into it: ſet it under the muffle of a furnace like that deſcribed in our Theoretical Elements, as peculiarly appropriated to this ſort of operation. Fill the furnace with charcoal; light it; make the cupel red-hot, and keep it ſo till all its moiſture be evaporated; that is, for about a good quarter of an hour, if the cupel be made wholly of the aſhes of burnt bones; and for a whole hour, if there be any waſhed wood-aſh in its compoſition.

Reduce the Regulus which remained after the preceding operation to little thin plates, flatting them with a ſmall hammer, and ſeparating them carefully from all the adherent ſcoria. Wrap theſe in a bit of paper, and with a ſmall pair of tongs put them gently into the cupel. When the paper is conſumed the Regulus will ſoon melt, and the ſcoria, which will be gradually produced by the Lead as it turns to litharge, will be driven to the ſides of the cupel, and immediately abſorbed thereby. At the ſame time the cupel will aſſume a yellow, brown, or blackiſh colour, according to the quantity and nature of the ſcoria imbibed by it.

When you ſee the matter in the cupel in a violent ebullition, and emitting much ſmoke, lower the fire by the methods formerly preſcribed. Keep up ſuch a degree of heat only that the ſmoke which aſcends from the matter may not riſe very high, and that you may be able to diſtinguiſh the colour which the cupel acquires from the ſcoria.

Increaſe the fire by degrees, as more and more litharge is formed and abſorbed. If the Regulus examined by this aſſay contain no Silver, you will ſee it turn wholly into ſcoria, and at laſt diſappear. When it contains Silver, and the quantity of Lead is much diminiſhed, you will perceive little vivid iriſes, or beautiful rain-bow colours, ſhooting ſwiftly along its ſurface, and croſſing each other in many different directions. At laſt, when all the Lead is deſtroyed, the thin dark ſkin, that is continually protruded by the Lead while it is turning into litharge, and which hitherto covered the Silver, ſuddenly diſappears; and, if at this moment the fire happen not to be ſtrong enough to keep the Silver in fuſion, the ſurface of that metal will at once dart out a dazling ſplendour: but, if the fire be ſtrong enough to keep the Silver in fuſion, though freed from all mixture of Lead, this change of colour, which is called its *fulguration*, will not be ſo perceptible, and the Silver will appear like a bead of fire.

Theſe phenomena ſhew that the operation is finiſhed. But the cupel muſt ſtill be left a minute or two under the muffle, and then drawn ſlowly out with the iron hook towards the door of the furnace. When the Silver is ſo cooled as to be but moderately red, you may take the cupel from under the muffle with your little tongs, and in the middle of its cavity you will find an exceeding white bead of Silver, the lower part whereof will be unequal, and full of little pits.

OBSERVATIONS.

THE Regulus obtained by the former proceſs conſiſts altogether of the Silver contained in the ore, alloyed with the other metals that happened to be mixed therewith in its mineral ſtate, and a good deal of the Lead that was added to precipitate the Silver. The operation of the cupel may be conſidered as the ſequel of that proceſs, being intended only to reduce into a ſcoria whatever is not Gold or

Silver. Lead being of all metals that which vitrifies the moſt eaſily, which moſt promotes the vitrification of the reſt, and the only one which, when vitrified, penetrates the cupel, and carries along with it the other metals which it hath vitrified, is conſequently the fitteſt for that purpoſe. We ſhall ſee in its place that Biſmuth hath the ſame properties with Lead, and may be ſubſtituted for it in this operation.

Care muſt be taken to chooſe a cupel of a proper capacity. Indeed it ſhould rather be too big than too little: becauſe the operation is no way prejudiced by an exceſs in its ſize; whereas if it be too ſmall it will be over-doſed with Lead, and at laſt the litharge, which deſtroys every thing, will corrode its cavity, and eat holes through the very body of the veſſel. Add that the aſhes, of which the cupel is made, being once glutted with litharge, abſorb it afterwards but ſlowly, and that the quantity of this vitrified litharge, becoming too great to be contained in the ſubſtance of the veſſel, exſudes through it, and drops on the floor of the muffle, which it corrodes and renders unequal; and moreover ſolders to it the veſſels ſet thereon. It may be laid down as a general rule for determining the ſize of a cupel, that it weigh at leaſt half as much as the metallic maſs to be refined in it.

It is alſo of the utmoſt conſequence that the cupel be well dried before the metal be put into it. In order to make ſure of this point it muſt be kept red-hot for a certain time, as is above directed: for though to the ſight and to the touch they appear very dry, they nevertheleſs obſtinately retain a ſmall matter of moiſture, ſufficient to occaſion the loſs of ſome of the metal; which, when it comes to melt, will be thereby ſpirted up, in the form of little globules, to the very roof of the muffle. The cupels, that ſtand moſt in need of an intenſe heat to dry them, are thoſe chiefly in whoſe compoſition wood-aſhes are employed: for whatever care be taken to lixiviate thoſe aſhes before they are uſed, they will ſtill retain a little alkaline ſalt; and that, we know, is very greedy of moiſture, will not part entirely with it but by the means of a violent calcination, and preſently re-imbibes it when expoſed to the air.

A little Phlogiſton alſo may ſtill be left in the aſhes of which the cupels are made; and that is another reaſon for calcining them before they are uſed. By this means the remaining Phlogiſton is diſſipated, which might otherwiſe combine with the litharge during the operation, reduce it, and occaſion ſuch a ferment in the matter as to make ſome of it run over: to theſe inconveniencies, which any remainder of moiſture or Phlogiſton may produce, we muſt add the cracks and flaws which are very incident to cupels not perfectly freed from both thoſe matters.

It is of no leſs importance to the ſucceſs of this operation, that a due degree of heat be kept up. In the proceſs we have deſcribed the marks which ſhew the heat to be neither too ſtrong nor too weak: when it exceeds in either of theſe reſpects may be known by the following ſigns.

If the fume emitted by the Lead riſe like a ſpout to the roof of the muffle; if the ſurface of the melted metal be extremely convex, conſidering the quantity of the maſs; if the cupel appear of ſuch a white heat that the colour communicated thereto by the imbibed ſcoria cannot be diſtinguiſhed: all theſe ſhew that the heat is too great, and that it ought to be diminiſhed. If on the contrary the vapours only hover, as it were, over the ſurface of the metal; if the melted maſs be very flat, conſidering its quantity; if its ebullition appear but faint; if the *ſcoriæ*, that appear like little fiery drops of rain, have but a languid motion; if the ſcoria gather in heaps, and do not penetrate the cupel; if the metal be covered with

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it as with a glaſſy coat; and laſtly, if the cupel look dull; theſe are proofs that the heat is too weak and ought to be encreaſed.

The deſign of this operation being to convert the Lead into litharge, and to give it ſufficient time and opportunity to ſcorify and carry off with it whatever is not Gold or Silver; the fire muſt be kept up to ſuch a degree that the Lead may eaſily be turned into litharge, and yet that litharge not be abſorbed too haſtily by the cupel, but that a ſmall quantity thereof may all along remain like a ring round the melted metal.

The fire is to be gradually increaſed as the operation draws nearer to its end: for, as the proportion of the Lead to the Silver is continually leſſening, the metallic maſs gradually becomes leſs fuſible; while the Silver defends the Lead mixed with it from the action of the fire, and prevents its being eaſily converted into litharge.

When the operation is finiſhed, the cupel muſt ſtill be left under the muffle till it has imbibed all the litharge, to the end that the bead of Silver may be eaſily taken out: for, without this precaution, it would ſtick ſo faſt as not to be removed, but by breaking off part of the cupel along with it. Care muſt alſo be taken to let this bead of Silver cool gradually, and be perfectly fixed before you draw it from under the muffle: for if you expoſe it at once to the cold air, before it be fixed, it will ſwell, ſhoot into ſprigs, and even dart out ſeveral little grains to a conſiderable diſtance, which will be loſt.

If the bead appear to have a yellowiſh tinge, 'tis a ſign that it contains a great deal of Gold, which muſt be ſeparated from it by the methods to be hereafter ſhewn.

It is proper to obſerve that there is ſcarce any Lead that does not contain ſome Silver; too little perhaps to defray the charges neceſſary to ſeparate it, yet conſiderable enough to lead us into an error, by mixing with the Silver obtained from an ore, and increaſing its weight. And therefore, when the operations above deſcribed are applied to the aſſaying of an ore, in order to know how much Silver it yields, it is previouſly neceſſary to examine the Lead to be uſed, and to aſcertain the quantity of Silver it contains, which muſt be deducted from the total weight of the bead of Silver obtained by purifying it in this manner.

Silver may be ſeparated from its ore, and at the ſame time refined, by the ſingle operation of the cupel, without any previous ſcorification with Lead. In order to do this, you muſt pound the ore; roaſt it, to diſſipate all its volatile parts; mix it with an equal quantity of litharge, if it be refractory; divide it into five or ſix parcels, wrapping each in a bit of paper; weigh out eight parts of granulated Lead for one of ore, if it be fuſible, and from twelve to ſixteen, if it be refractory; put one half of the Lead into a very large cupel under the muffle; add thereto one of the little parcels of ore, when the Lead begins to ſmoke and boil; immediately ſlacken the fire a little; continue the ſame degree of heat till you perceive that the litharge formed round the metal, and on its ſurface, begins to look bright; then raiſe the fire; add a freſh parcel of ore; continue proceeding in the ſame manner till you have put in all the ore; then add the remaining half of the granulated Lead, and conduct the ſucceeding part of the operation in the ſame manner as that of cupelling.

In this operation it is neceſſary that the fire be not too ſtrongly urged, and that it be diminiſhed every time you add a freſh parcel of ore; that ſo the Lead and the litharge may have time to diſſolve, ſcorify, and carry off into the pores of the cupel, all the adventitious matters with which your Silver may be mixed. Notwithſtanding this precaution, when the ore is refractory, there often gathers in the cupel a great quantity of ſcoria, together alſo with ſome of the ore that could not be diſſolved and ſcorified. It is with a view to remedy this inconvenience that the ſecond moiety of the Lead is added towards the end, which completes the diſſolution and ſcorification of the whole; ſo that by means thereof no ſcoria, or very little, is left in the cupel at the end of the operation.

The operation of the cupel is chiefly uſed to purify Silver from the alloy of Copper; becauſe this metal, being more fixed and harder to calcine than other metallic ſubſtances, is the only one that remains united with Silver and Lead, after roaſting and ſcorification with Lead. It requires no leſs than ſixteen parts of Lead to deſtroy it in the cupel, and ſeparate it from Silver. It melts into one maſs with the Lead; and the glaſs produced by theſe two metals, deprived of their phlogiſton, inclines to a brown or a black colour; by which appearance chiefly we know that our Silver was alloyed with Copper.

PROCESS III.

To purify Silver by Nitre.

GRANULATE the Silver you intend to purify, or reduce it to thin plates; put it into a good crucible; add thereto a fourth part in weight of very dry pulverized Nitre, mixed with half the weight of the Nitre of calcined Wine-lees, and about a ſixth part of the ſame weight of common glaſs in powder. Cover this crucible with another crucible inverted, which muſt be of ſuch a ſize that its mouth may enter a little way into that of the lower one, and have its bottom pierced with a hole of about two lines in diameter. Lute the two crucibles together with clay and Windſor-loam. When the lute is dry, place the crucibles in a melting furnace. Fill the furnace with charcoal, taking care however that they do not riſe above the upper crucible.

Kindle the fire, and make your veſſels of a middling red heat. When they are ſo, take up with the tongs a live coal, and hold it over the hole of the upper crucible. If you immediately perceive a vivid ſplendour round the coal, and at the ſame time hear a gentle hiſſing noiſe, it is a ſign that the fire is of a proper ſtrength; and it muſt be kept up at the ſame degree till this phenomenon ceaſe.

Then increaſe the fire to the degree requiſite to keep pure Silver in fuſion; and immediately take your veſſels out of the furnace. You will find the Silver at the bottom of the lower crucible, covered with a maſs of alkaline ſcoria of a greeniſh colour. If the metal be not rendered perfectly pure and ductile by this operation, it muſt be repeated a ſecond time.

OBSERVATIONS.

THE purification of Silver by Nitre, as well as the proceſs for refining it on the cupel, is founded on the property which this metal poſſeſſes of reſiſting the force of the ſtrongeſt fire, and the power of the moſt active ſolvents, without loſing its phlogiſton. The difference between theſe two operations conſiſts wholly in the ſubſtances made uſe of to procure the ſcorification of the imperfect metals, or ſemi-metals, that may be combined with the Silver. In the former this was obtained by Lead, and here it is effected by Nitre. This Salt, as we have ſhewn, hath the property of calcining and quickly deſtroying all metallic ſubſtances, by conſuming their phlogiſton, except the perfect metals, Gold and Silver, which alone are able to reſiſt its force. This method may therefore be employed to purify Gold as well as Silver, or indeed both the two mixed together.

In this operation the Nitre is gradually alkalizated as its Acid is conſumed with the phlogiſton of the metallic ſubſtances. The Alkaline Salt and pounded glaſs are added with a view to promote the fuſion of the metalline calxes as faſt as they are formed, and to fix and retain the Nitre, which, as we ſhall preſently ſee, is apt to fly off in a certain degree of heat.

The precaution of covering the crucible with another crucible inverted, which hath only a ſmall hole in its bottom, is deſigned to prevent any of the Silver from being loſt in the operation: for when the Nitre comes to be acted on by a certain degree of heat, and eſpecially when it deflagrates with any inflammable matter, part of it flies off, and ſo rapidly too as to be capable of carrying off with it a good deal of the Silver. The little hole left in the covering crucible is neceſſary for giving vent to the vapours which riſe during the deflagration of the Nitre, as they would otherwiſe open themſelves a paſſage by burſting the veſſels. After the operation this vent-hole is found beſet with many little particles of Silver, which would have been loſt if the crucible had not been covered.

If you ſhould obſerve, during the detonation of the Nitre, that a great many vapours iſſue through the vent-hole with a conſiderable hiſſing noiſe, even without applying the coal, you muſt take it for a ſign that the fire is too briſk, and accordingly check it; elſe a great deal of the Nitre will be diſſipated, and with it much Silver.

You muſt obſerve to take the Silver out of the fire as ſoon as it is in fuſion: for if you neglect this, the Nitre being entirely diſſipated or alkalizated, the calxes of the metals deſtroyed by it may poſſibly recover a little phlogiſton, communicated either by the vapours of the charcoal, or by little bits of coal accidentally falling into the crucible; by which means ſome portion of thoſe metals being reduced will mix again with the Silver, prevent its having the deſired degree of purity and ductility, and oblige you to begin the operation afreſh.

PROCESS IV.

To diſſolve Silver in Aqua Fortis, *and thereby ſeparate it from every other metalline Subſtance. The Purification of* Aqua Fortis. *Silver precipitated by Copper.*

THE Silver you intend to diſſolve being beaten into thin plates, put it into a glaſs cucurbit; pour on it twice its weight of good precipitated *Aqua Fortis*; cover the cucurbit with a paper, and ſet it on a ſand-bath moderately heated. The *Aqua Fortis* will begin to diſſolve the Silver as ſoon as it comes to be a little warm. Red vapours will riſe; and from the upper ſurfaces of the Silver there will ſeem to iſſue ſtreams of little bubbles, aſcending to the top of the liquor, between which and the Silver they will form, as it were, a number of fine chains: this is a ſign that the diſſolution proceeds duly, and that the degree of heat is ſuch as it ought to be. If the liquor appear to boil and be agitated, a great many red vapours riſing at the ſame time, it is a ſign that the heat is too great, and ſhould be leſſened till it be reduced to the proper degree indicated above: having obtained that, keep it equally up till no more bubbles or red vapours appear.

If your Silver be alloyed with Gold, the Gold will be found, when the diſſolution is finiſhed, at the bottom of the veſſel in the form of a powder. The ſolution muſt now be decanted while it is yet warm: on the powder pour half as much freſh *Aqua Fortis* as before, and make it boil; again decant this ſecond *Aqua Fortis*, and repeat the ſame a third time; then with fair water waſh the remaining powder well: it will be of a brown colour inclining to red. In the obſervations we ſhall ſhew how the Silver is to be ſeparated from the *Aqua Fortis.*

OBSERVATIONS.

ALL the proceſſes on Silver already delivered, whether for extracting it from its ores, or for refining it, either by the Cupel or by Nitre, are applicable to Gold alſo. And if Silver be alloyed with Gold before it undergo thoſe ſeveral operations, it will ſtill remain alloyed therewith after them, in the ſame manner, and in the ſame quantity; becauſe both metals bear them equally. All therefore, that can be expected from thoſe ſeveral aſſays, is the ſeparation of every thing that is neither Silver nor Gold from theſe two metals. But in order to ſeparate theſe two from each other, recourſe muſt be had either to the proceſs laid down under the head of Gold, or to that here deſcribed, which is the moſt commodious, the moſt uſual, and known by the names of *Quartation* and the *Parting Aſſay.*

Aqua Fortis is the true Solvent of Silver, and is utterly incapable of diſſolving the leaſt atom of Gold. If therefore a maſs conſiſting of Gold and Silver be expoſed to the action of *Aqua Fortis,* that Acid will diſſolve the Silver contained in the compound, without touching the Gold, and the two metals will be ſeparated from each other. This method of parting them is juſt the reverſe of that deſcribed before under the head of Gold, which is effected by the means of *Aqua Regis.*

To the ſucceſs of this ſeparation by means of *Aqua Fortis* ſeveral conditions are eſſentially neceſſary. The firſt is that the Gold and Silver be in due proportion to each other; that is, there muſt be at leaſt twice as much Silver as Gold in the metalline maſs, otherwiſe the *Aqua Fortis* will not be able to diſſolve it, for the reaſon formerly given. If therefore the maſs contain too little Silver, it muſt either be melted down again, and a proper quantity of Silver added; or elſe, if the Gold be in a ſufficient proportion to the Silver, they may be parted by means of *Aqua Regis*.

Secondly, it is neceſſary that the *Aqua Fortis* employed in this operation be abſolutely pure, and free from any taint of the Vitriolic or Marine Acid: for, if it be adulterated with the Vitriolic Acid, the Silver will precipitate as faſt as it diſſolves, and ſo the precipitated Silver will again mix with the Gold. If the *Aqua Fortis* contain any of the Marine Acid, the Silver will be precipitated in that caſe alſo; and this inconvenience will be attended with another, namely, that the menſtruum, being partly an *Aqua Regis*, will diſſolve ſome of the Gold. You muſt therefore be very ſure that your *Aqua Fortis* is pure before you ſet about the operation. In order to diſcover its quality, you muſt try it by diſſolving, in a ſmall portion thereof, as much Silver as it will take up: if the *Aqua Fortis* grow opaque and milky as it diſſolves the Silver, 'tis a ſign it contains ſome foreign Acid, from which it muſt be purified.

In order to effect this, let the portion of *Aqua Fortis* uſed for the above trial ſtand to ſettle: the white milky part will gradually fall to the bottom of the veſſel. When it is all fallen, gently decant the clear liquor, and pour a few drops of this decanted ſolution of Silver into the *Aqua Fortis* which you want to purify. It will inſtantly become milky. Let the white particles precipitate as before, and then add a few more drops of your ſolution of Silver. If the *Aqua Fortis* ſtill become milky, let it precipitate again, and repeat this till you find that a drop of your Solution of Silver, let fall into this *Aqua Fortis*, does not make it in the leaſt turbid. Then filter it through brown paper, and you will have an *Aqua Fortis* perfectly fit for the Parting Aſſay.

The white particles that appear and ſettle to the bottom, on diſſolving Silver in an *Aqua Fortis* adulterated with a mixture of ſome foreign Acid, are no other than that very Silver, which is no ſooner diſſolved by the Nitrous Acid than it deſerts that ſolvent to unite with the Vitriolic or Marine Acid, wherewith it has a greater affinity, and falls to the bottom with them. And this happens as long as there remains in the *Aqua Fortis* a ſingle atom of either of thoſe two Acids.

When therefore your *Aqua Fortis* hath diſſolved as much Silver as it is capable of taking up, and when all the white particles formed during the diſſolution are ſettled to the bottom, you may be aſſured that the portion which remains clear and limpid is a ſolution of Silver in an exceeding pure *Aqua Fortis*. But if the ſolution of Silver thus depurated be mixed with an *Aqua Fortis* adulterated with the Vitriolic or Marine Acid, a like precipitation will immediately enſue, for the reaſons above given, till the very laſt particle of the heterogeneous Acid contained in the *Aqua Fortis* be precipitated.

Aqua Fortis purified by this method contains no extraneous ſubſtance whatever, except a ſmall portion of Silver; ſo that it is very fit for the parting proceſs. But if it be intended for other chymical purpoſes, it muſt be rectified in a glaſs retort with a moderate heat, in order to ſeparate it from the ſmall portion of Silver it contains, which will remain at the bottom of the retort.

The third condition neceſſary to the ſucceſs of this operation is that your *Aqua Fortis* be neither too aqueous, nor too highly concentrated. If too weak, it will not act upon the Silver: and the conſequence will be the ſame if it be too ſtrong. Both theſe inconveniencies are eaſily remedied: for in the former caſe part of the ſuperfluous phlegm may be drawn off by diſtillation; or a ſufficient quantity of much ſtronger *Aqua Fortis* may be mixed with that which is too weak: and in the latter caſe, very pure rain water, or a weaker *Aqua Fortis*, may be mixed with that which is too ſtrong.

You may ſatisfy yourſelf whether or no your *Aqua Fortis* hath the requiſite degree of ſtrength, by diſſolving therein a thin plate conſiſting of one part Gold and two or three parts Silver; which plate muſt be rolled up in form of a paper coffin. If, when all the Silver contained in the plate is diſſolved, the Gold remains in the form of the coffin, it is a ſign that your Solvent has a due degree of ſtrength. If, on the contrary, the Gold be reduced to a powder, it is a proof that your *Aqua Fortis* is too ſtrong, and ought to be weakened.

The Gold remaining after the diſſolution of the Silver muſt be melted in a crucible with Nitre and Borax, as hath already been ſaid under the proceſs for parting Gold and Silver by means of *Aqua Regis*. As to the Silver which remains diſſolved in the *Aqua Fortis*, there are ſeveral ways to recover it.

The moſt uſual is to precipitate it by the interpoſition of Copper, which hath a greater affinity than Silver with the Nitrous Acid *. For this purpoſe the ſolution is weakened by adding twice or thrice as much very pure rain water. The cucurbit containing the ſolution is ſet on a ſand-bath gently heated, and very clean plates of copper put into it. The ſurfaces of theſe plates are ſoon covered with little white ſcales, which gradually fall to the bottom of the veſſel, as they come to be collected in quantities. It is even proper to ſtrike the cucurbit gently now and then, in order to ſhake the ſcales of Silver from the copper plates, and ſo make room for a new crop.

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* See the Table of Affinities Column IV.

The *Aqua Fortis* parts with the Silver by degrees only as it diſſolves the Copper; and therefore the liquor gradually acquires a blueiſh green colour as the precipitation advances. This precipitation of the Silver is to be continued as long as any remains diſſolved in the *Aqua Fortis:* you may be ſure that your liquor contains no more Silver, if the ſurface of a freſh plate of copper laid therein remain clean and free from aſh-coloured or greyiſh particles; or if one drop of a ſolution of Sea-ſalt let fall into it produce no white or milky cloud.

The precipitation being finiſhed, the liquor is to be gently poured off from the precipitated Silver, which muſt be rinſed in ſeveral waters, and even made to boil therewith, in order to free it wholly from the diſſolved Copper. The Silver thus well waſhed muſt be thoroughly dried, mixed with a fourth of its weight of a flux compounded of equal parts of Nitre and calcined Borax, and then melted in a crucible. On this occaſion care muſt be taken to raiſe the fire gently and gradually, till the Silver be brought to fuſion.

With what accuracy ſoever the precipitated Silver be waſhed, in order to free it from the ſolution of Copper, yet the Silver will always be found alloyed with a ſmall portion of the Copper: but then this Copper is eaſily deſtroyed by the Nitre, with which the Silver is afterwards melted; ſo that the latter metal remains perfectly pure after the operation.

Though the Silver be not previouſly cupelled, but be alloyed with other metallic ſubſtances at the time it is thus diſſolved, yet the diſſolving, precipitating, and fuſing it with Nitre would be ſufficient to ſeparate it accurately from them all, and refine it to a degree of purity equal to that obtained by the cupel.

The Copper that remains diſſolved in the *Aqua Fortis*, after the precipitation of the Silver, may in like manner be precipitated by Iron, and, as it retains

tains a ſmall portion of Silver, ought not to be neglected when theſe operations are performed on conſiderable quantities.

In the two next proceſſes we ſhall ſhew two other methods of ſeparating Silver from *Aqua Fortis*.

PROCESS V.

To ſeparate Silver from the Nitrous Acid by Diſtillation. Cryſtals of Silver. The Infernal Stone.

INTO a large, low, glaſs body put the ſolution of Silver from which you intend to ſeparate the Silver by diſtillation. To this body fit a tubulated head provided with its ſtopple. Set this alembic in a ſand-bath, ſo that the body may be almoſt covered with ſand: apply a receiver, and diſtill with a moderate heat, ſo that the drops may ſucceed each other at the diſtance of ſome ſeconds. If the receiver grow very hot, check the fire. When red vapours begin to appear, pour into the alembic, through the hole in its head, a freſh quantity of your ſolution of Silver, firſt made very hot. Continue diſtilling in this manner, and repeating the addition of freſh liquor, till all your ſolution be put into the alembic. When you have no more freſh ſolution to put in, and when, the phlegm being all come over, red vapours begin again to appear, convey into the alembic half a dram or a dram of tallow, and diſtill to dryneſs; which being done, increaſe your fire ſo as to make the veſſel containing the ſand-bath red-hot. In the alembic you will find a calx of Silver, which muſt be melted in a crucible with ſome ſoap and calcined wine-lees.

OBSERVATIONS.

A low cucurbit is recommended for this operation, to the intent that the particles of the Nitrous Acid, which are ponderous, may the more eaſily be carried up and paſs over into the receiver. For the ſame reaſon the cucurbit is directed to be almoſt wholly covered with ſand; leſt otherwiſe the acid vapours ſhould be condenſed about that part of the cucurbit, which, being out of the ſand, would be much cooler than that which is encompaſſed therewith, and from thence fall back again to the bottom; by which means the diſtillation would certainly be retarded, and the veſſel would probably be broken.

Notwithſtanding theſe precautions the veſſels are liable to break in ſuch diſtillations; eſpecially when they contain a great deal of liquor. With a view therefore to prevent this accident, we ordered that the whole quantity of the ſolution of Silver to be diſtilled ſhould not be put at once into the alembic. The little bit of tallow added towards the end of the operation is intended to hinder the metal from adhering cloſely to the veſſel, as it would otherwiſe do, when all the moiſture is diſſipated.

The Soap and Fixed Alkali mixed with the Silver to flux it, after its ſeparation from the *Aqua Fortis* in this way, ſerve to abſorb ſuch of the moſt fixed particles of the Acid as may ſtill remain united with the metal.

If the diſtillation be ſtopped when part of the phlegm is drawn off, and the liquor be then ſuffered to cool, many cryſtals will ſhoot therein, which are a Neutral Salt conſtituted of the Nitrous Acid and Silver. If the diſtillation be carried further, and ſtopped when near its concluſion, the liquor being then ſuffered to cool will wholly coagulate into a blackiſh maſs called the *Infernal Stone*.

This way of ſeparating Silver from its ſolvent is attended with the advantage of ſaving all the *Aqua Fortis*, which is excellent, and fit to be employed in other operations.

PROCESS VI.

To ſeparate Silver from the Nitrous Acid by Precipitation. Luna Cornea. Luna Cornea *reduced.*

INTO your ſolution of Silver pour about a fourth part in weight of Spirit of Salt, ſolution of Sea-ſalt, or ſolution of Sal Ammoniac. The liquor will inſtantly become turbid and milky. Add twice or thrice its weight of fair water, and let it ſtand ſome hours to ſettle. It will depoſite a white powder. Decant the clear liquor, and on the precipitate pour freſh *Aqua Fortis*, or Spirit of Salt, and warm the whole on a ſand-bath with a gentle heat for ſome time. Pour off this ſecond liquor, and boil your precipitate in pure water, ſhifting it ſeveral times, till the precipitate and the water be both quite inſipid. Filter the whole, and dry the precipitate, which will be a *Luna Cornea*, and muſt be reduced in the following manner.

Smear the inſide of a good crucible well with ſoap. Put your *Luna Cornea* into it; cover it with half its weight of Salt of Tartar, thoroughly dried and pulveriſed; preſs the whole hard down; pour thereon as much oil, or melted tallow, as the powder is capable of imbibing; ſet the crucible thus charged, and cloſe covered, in a melting furnace, and, for the firſt quarter of an hour, kindle no more fire than is neceſſary to make the crucible moderately red; after that raiſe it ſo as to melt the Silver and the Salt, throwing into the crucible from time to time little bits of tallow. When it ceaſes to ſmoke, let the whole cool; or pour it into a hollow iron cone, warmed and tallowed.

OBSERVATIONS.

THE proceſs here delivered furniſhes us with the means of procuring Silver in a degree of purity which is not to be obtained by any other method of treating it whatever. That which is refined on the cupel always retains a ſmall portion of copper, from which it cannot poſſibly be ſeparated in that way: but if it be diſſolved in *Aqua Fortis*, and precipitated thence in a *Luna Cornea* by the Marine Acid, the precipitate will be an abſolutely pure Silver, unalloyed with that ſmall portion of Copper which it retained on the cupel. The reaſon of this effect is, that the Copper remains as perfectly diſſolved in Spirit of Salt and in *Aqua Regia* as in *Aqua Fortis*: ſo that when the Silver and the Copper with which it is alloyed are diſſolved together in the Nitrous Acid, if the Acid of Sea-ſalt be mixed with the ſolution, part of this latter Acid unites with the Silver, and therewith forms a new compound, which not being ſoluble in the liquor, falls to the bottom. The other part of the Acid mixing with the Nitrous, forms an *Aqua Regis*, in which the Copper remains diſſolved, without ſeparating from it.

Freſh Acid is poured on the precipitated calx of Silver, in order to complete the ſolution of the ſmall portion of Copper that may have eſcaped the action of the firſt ſolvent. It is indifferent whether the Spirit of Salt or the Spirit of Nitre be employed for this purpoſe, becauſe they both diſſolve Copper alike, and becauſe Silver precipitated by Spirit of Salt is not ſoluble in either.

After this it is neceſſary to waſh the precipitate well with pure water, in order to free it entirely from the particles of *Aqua Fortis* adhering to the Silver; becauſe they may poſſibly contain ſomething of

Copper, which would mix with the Silver in melting, and taint its purity.

If this precipitate of Silver be expoſed to the fire, unmixed with any other ſubſtance, it melts as ſoon as it begins to be red; and if the fire be increaſed, part thereof will be diſſipated in vapours, and the reſt will make its way through the crucible in which you melt it. But being poured out of the crucible as ſoon as melted, it coagulates into a cake of a purpliſh red colour, ſemi-tranſparent, ponderous, and in ſome degree pliable, eſpecially if it be very thin. It bears ſome reſemblance to horn, which hath occaſioned it to be called *Luna Cornea.*

As *Luna Cornea* is not ſoluble in water, recourſe muſt be had to fuſion, in order to reduce it by ſeparating from the Silver thoſe acids which give it the abovementioned properties. Fixed Alkalis and fatty matters are very fit to produce that ſeparation.

We directed that the inſide of the crucible, in which the reduction is to be made, ſhould be carefully ſmeared with ſoap, and that the *Luna Cornea* ſhould be quite covered with a Fixed Alkali and fat, to the end that when the heat is ſtrong enough to diſſipate it in vapours, or to attenuate it ſo as to render it capable of penetrating the crucible, it may be forced to paſs through matters qualified to abſorb its Acid, and reduce it.

Luna Cornea may alſo be reduced by being melted with ſuch metalline ſubſtances as have a greater affinity than Silver with the Acids wherewith it is impregnated. Of this kind are Tin, Lead, Regulus of Antimony: but the *Luna Cornea* ruſhes ſo impetuouſly into conjunction with thoſe metalline ſubſtances, that a vaſt many vapours ariſe, and carry off with them part of the Silver: if therefore you chuſe to effect the reduction by the interpoſition of ſuch metalline ſubſtances, you muſt employ a retort inſtead of a crucible.

But this method is attended with another inconvenience; which is, that ſome part of thoſe metalline ſubſtances may unite with the Silver, and adulterate it; for which reaſon it is beſt to keep to the method firſt propoſed.

PROCESS VII.

To diſſolve Silver, and ſeparate it from Gold, by Cementation.

MIX thoroughly together fine brick-duſt four parts, Vitriol calcined to redneſs one part, and Sea ſalt or Nitre one part. Moiſten this powder with a little water. With this cement cover the bottom of a crucible half an inch thick; on this firſt bed lay a thin plate of the maſs of Gold and Silver you intend to cement, and which you muſt previouſly take care to beat into ſuch thin plates. Cover this plate with a ſecond layer of cement, of the ſame thickneſs as the former; on this ſecond bed lay another plate of your metal; cover it in like manner with cement; and ſo proceed till the crucible be filled to within half an inch of its brim. Fill up the remaining ſpace with cement, and cloſe the crucible with a cover, luted with a paſte made of Windſor-loam and water: ſet your crucible thus charged in a furnace, whoſe fire-place is deep enough to let it be entirely ſurrounded with coals, quite up to its mouth. Light ſome coals in the furnace, taking care not to make the fire very briſk at firſt; encreaſe it by degrees, but only ſo far as to make the crucible moderately red; keep up the fire in this degree for eighteen or twenty hours: then let the fire go out; open the crucible when it is cold, and ſeparate the cement from your plates of Gold. Boil the Gold repeatedly in fair water, till the water come off quite inſipid.

OBSERVATIONS.

IT cannot but ſeem ſtrange that, after having ſo often declared the Acid of Sea-ſalt to be incapable of diſſolving Silver, we ſhould direct either Nitre or Sea-ſalt indifferently to be employed in compoſing a cement, which is to produce an Acid capable of eating out all the Silver mixed with Gold. It is eaſy to conceive how the Nitrous Acid extricated from its baſis by means of the Vitriolic Acid may produce this effect: but if Sea-ſalt inſtead of Nitre be made an ingredient in the cement, its Acid, though ſet at liberty in the ſame manner by the Vitriolic Acid, muſt at firſt ſight appear unable to anſwer the end.

In order to remove this difficulty we muſt here obſerve that there are two very eſſential differences between the Marine Acid collected in a liquor, as it is when diſtilled in the uſual manner, and the ſame Acid ſeparated from its baſis in a crucible, as it is in cementation.

The firſt of theſe two differences is that, the Acid being reduced into vapours when it acts on the Silver in cementation, its activity is thereby greatly encreaſed: the ſecond is, that in the crucible it ſuſtains a vaſtly greater degree of heat than it can ever bear when it is in the form of a liquor. For, after it is once diſtilled and ſeparated from its baſis, it cannot ſuſtain any extraordinary degree of heat without being volatilized and entirely diſſipated: whereas while it continues united with its baſis it is much more fixed, and cannot be ſeparated but by a very intenſe heat. Conſequently, if it meet with any body to diſſolve, at the very inſtant of its ſeparation from its baſis, while it is actuated by a much fiercer heat than can ever be applied to it on any other occaſion, it muſt operate upon that body with ſo much the more efficacy: and thus it comes to paſs that in cementation it has the power of diſſolving Silver, which it would be incapable of touching if it were not ſo circumſtanced.

But herein Gold differs from Silver: for, whatever force the Nitrous or the Marine Acid may exert, when extricated from their baſes in the cementing crucible, this metal obſtinately refuſes to yield to either of thoſe Acids ſeparately, and can never be diſſolved by them, unleſs both be united together.

Our cementation therefore is actually a parting proceſs in the dry way. The Silver is diſſolved, and the Gold remains unaltered. Nay, as the action of the Acids is much ſtronger when they are applied this way, than when they are uſed for diſſolution in the moiſt way, the Nitrous Acid, which in the common parting proceſs will not diſſolve Silver unleſs its weight be double that of the Gold, is able in cementation to diſſolve a very ſmall quantity of Silver diffuſed through a large quantity of Gold.

It ſometimes happens that after the operation the cement proves extremely hard, ſo that it is very troubleſome to ſeparate it entirely from the Gold. In this caſe it muſt be ſoftened by moiſtening it with hot water. This hardneſs which the cement acquires is occaſioned by the fuſion of the Salts, which is the effect of too ſtrong a heat. It was in order to prevent this, and that a due degree of heat might be applied without the danger of melting the ſalts, that we directed the cement to be mixed with a conſiderable quantity of earthy matter incapable of fuſion, ſuch as brick-duſt. A greater inconvenience ſtill will enſue if the fire be made ſo ſtrong as to melt the Gold: for then it will partly commix again with the other metalline ſubſtances diſſolved by the cement, and conſequently will not be purified.

The crucible is covered, and its cover luted on, to prevent the acid vapours from being too ſoon diſſipated, and to force them to circulate the longer in the crucible. However, it is neceſſary that thoſe vapours ſhould find a vent at laſt, otherwiſe they would burſt the veſſel: and for this reaſon we directed the crucible to be luted only with Windſor-loam, which does not grow very hard by the action of fire, and ſo is capable of yielding and giving paſſage to the vapours, when a certain quantity of them is collected in the crucible, and they begin to ſtruggle for an eſcape on every ſide.

When the operation is finiſhed, the Silver diſſolved by the Acid of the cement is partly diſtributed through the cement, and partly in the Gold itſelf, which is impregnated therewith. For this reaſon the Gold muſt be waſhed ſeveral times in boiling water, till the water become abſolutely inſipid: for, if the Gold be melted without this precaution, it will mix again with the Silver: the cement alſo may be waſhed in the ſame manner to recover the Silver it contains.

Though this cementation be, properly ſpeaking, a purification of Gold, yet we have placed it among the proceſſes on Silver, becauſe it is the Silver that is diſſolved on this occaſion, and becauſe this is a particular way of diſſolving that metal. Moreover, moſt of the proceſſes hitherto delivered, either on Gold or Silver, are equally applicable to both theſe metals.

If the Gold do not appear quite pure after the cementation, the proceſs muſt be repeated.

There are ſeveral ways to know the fineneſs of Gold, the quantity of Silver with which it is alloyed, and the proportion in which theſe two metals are mixed in a maſs purified by the cupel.

One of the ſimpleſt is the trial by the Touch-ſtone; which indeed is hardly any more than judging by the eye only, from the colour of the compound metal, what proportion of Gold and Silver it contains.

The Touch-ſtone is a ſort of black marble, whoſe ſurface ought to be half poliſhed. If the metalline maſs which you want to try be rubbed on this ſtone, it leaves thereon a thin coat of metal, the colour of which may be eaſily obſerved. Such as are accuſtomed to ſee and handle Gold and Silver can at once judge very nearly from this ſample in what proportion the two metals are combined: but, for greater accuracy, thoſe who are in the way of having frequent occaſion for this trial are provided with a ſufficient number of ſmall bars or needles, of which one is pure Gold, another pure Silver, and all the reſt conſiſt of theſe two metals mixed together in different proportions, varied by carats, or even by fractions of carats, if greater exactneſs be required.

The fineneſs of each needle being marked on it, that needle whoſe colour ſeems to come neareſt the colour of the metalline ſtreak on the Touch-ſtone is rubbed on the ſtone by the ſide of that ſtreak. This needle likewiſe leaves a mark; and if there appear to be no difference between the two metalline ſtreaks, the metalline maſs is judged to be of the ſame fineneſs as the needle thus compared with it. If the eye diſcovers a ſenſible difference, another needle is ſought for whoſe colour may come nearer to that of the metal to be tried. But though a man be ever ſo well verſed in judging thus of the fineneſs of Gold by the eye only, he can never be perfectly and accurately ſure of it by this means alone. If ſuch certainty be required, recourſe muſt be had to the parting aſſay; and yet when you have gone through it, there always remains a ſmall quantity of the metal, which ſhould have been diſſolved, and yet eſcaped the action of the ſolvent. For example, if you make uſe of *Aqua Regis*, the Silver that remains after the operation ſtill contains a little Gold; and, if you make uſe of *Aqua Fortis*, the Gold that remains after the operation ſtill contains a little Silver. And therefore if you reſolve to carry the ſeparation of theſe two metals ſtill further by ſolvents, it will be neceſſary, after you have gone through one parting proceſs, to perform a ſecond the contrary way. For example, if you begin with *Aqua Fortis*, then, after it has diſſolved all the Silver in the metalline maſs that it is capable of taking up, diſſolve the remaining Gold in *Aqua Regis*; by which means you will ſeparate the ſmall portion of Silver left in it by the *Aqua Fortis*. The contrary is to be done if you made uſe of *Aqua Regis* firſt.

CHAP. III.

Of COPPER.

PROCESS I.

To ſeparate Copper from its Ore.

BEAT your Copper ore to a fine powder, having firſt freed it as accurately as poſſible, by waſhing and roaſting, from all ſtony, earthy, ſulphureous, and arſenical parts. Mix your ore thus pulverized with thrice its weight of the black flux; put the mixture into a crucible; cover it with common ſalt to the thickneſs of half an inch, and preſs the whole down with your finger. With all this the crucible muſt be but half full. Set it in a melting furnace; kindle the fire by degrees, and raiſe it inſenſibly till you hear the Sea-ſalt crackle. When the decrepitation is over, make the crucible moderately red-hot for half a quarter of an hour. Then give a conſiderable degree of heat, exciting the fire with a pair of good perpetual bellows, ſo that the crucible may become very red-hot, and be perfectly ignited. Keep the fire up to this degree for about a quarter of an hour; then take out the crucible, and with a hammer ſtrike a few blows on the floor on which you ſet it. Break it when cold. If the operation hath been rightly and ſucceſsfully performed, you will find at the bottom of the veſſel a hard Regulus, of a bright yellow colour, and ſemi-malleable; and over it a ſcoria of a yellowiſh brown colour, hard and ſhining, from which you may ſeparate the Regulus with a hammer.

OBSERVATIONS.

COPPER in the ore is often blended with ſeveral other metallic ſubſtances, and with volatile minerals, ſuch as Sulphur and Arſenic. Copper ores alſo frequently participate of the nature of the pyrites, containing a martial and an unmetallic earth, both of which are entirely refractory, and hinder the ore from melting. In this caſe you muſt add equal parts of a very fuſile glaſs, a little borax, and four parts of the black flux, to facilitate the fuſion. The black flux is moreover neceſſary to furniſh the Copper with the Phlogiſton it wants, or reſtore ſo much thereof as it may loſe in melting. For the ſame reaſon, when any ore, but that of Gold or Silver, is to be ſmelted, it is a general rule to add ſome black flux, or other matter abounding with Phlogiſton.

The Regulus produced by this operation is not malleable, becauſe it is not pure Copper, but a mixture of Copper with all the other metallic ſubſtances that were in the ore; except ſuch as were ſeparated from it by roaſting, of which it contains but little.

According to the nature of the metallic matters that remain combined with the Copper after this fuſion, the colour of the Regulus is either like that of pure Copper, or a little more whitiſh: it is alſo frequently blackiſh, which has procured it the name of *Black Copper*. In this ſtate, and even in general, it is uſual enough to call this Regulus by the name of Black Copper, when alloyed with other metallic ſubſtances that render it unmalleable, whatever its colour be.

Hence it appears that there may be ſeveral different ſorts of Black Copper. Iron, Lead, Tin, Biſmuth, and the reguline part of Antimony, are almoſt always combined with the ores of Copper, in a multitude of different proportions; and all theſe ſubſtances, being reduced by the black flux in the operation, mix and precipitate with the Copper. If the ore contain any Gold or Silver, as is pretty often the caſe, theſe two metals alſo are confounded with the reſt in the precipitation, and become part of the Black Copper.

Pyritoſe, ſulphureous, and arſenical Copper ores may be fuſed, in order to get rid of the groſſer heterogeneous parts, without previouſly roaſting them: but in this caſe no alkaline flux muſt be mixed with the ore; becauſe the Alkali in combination with the Sulphur would produce a Liver of Sulphur, and ſo diſſolve the metalline part; by which means all would be confounded together, and no Regulus, or very little, be precipitated. On this occaſion therefore nothing muſt be added to promote the fuſion, but ſome tender fuſile glaſs, together with a ſmall quantity of borax.

This firſt fuſion may alſo be performed amidſt the coals, by caſting the ore upon them in the furnace, without uſing a crucible; and then an earthen veſſel, thoroughly heated, or even made red-hot, muſt be placed under the grate of the fire place, to receive the metal as it runs from the ore.

The Regulus obtained by this means is much more impure and brittle than Black Copper, becauſe it contains moreover a large quantity of Sulphur and Arſenic; as theſe volatile ſubſtances have not time to evaporate during the ſhort ſpace requiſite to melt the ore, and as they cannot be carried off by the action of the fire after the ore is once melted, whatever time be allowed for that purpoſe. However ſome part thereof is diſſipated, and the Iron which is in pyritoſe ores, having a much greater affinity than Copper, and indeed than any other metallic ſubſtance, with Sulphur and Arſenic, abſorbs another part thereof, and ſeparates it from the Regulus.

This Regulus, it is plain, ſtill contains all the ſame parts that were in the ore, but in different proportions; there being more Copper, combined with leſs Sulphur, Arſenic, and unmetallic earth, which have been either diſſipated or turned to ſlag. Therefore if you would make it like Black Copper, you muſt pound it, roaſt it over and over, to free it from its Sulphur and Arſenic, and then melt it with the black flux.

If this Regulus contain much Iron, it will be adviſeable to melt it once or twice more, before all the Sulphur and Arſenic are ſeparated from it by roaſting; for as the Iron, by uniting with theſe volatile ſubſtances, ſeparates them from the Copper, with which they have not ſo great an affinity; ſo alſo the Sulphur and Arſenic, by uniting with the Iron, help in their turn to ſeparate it from the Copper.

* * *

PROCESS II.

To purify Black Copper, and render it malleable.

BREAK into ſmall bits the Black Copper you intend to purify; mix therewith a third part in weight of granulated Lead, and put the whole into a cupel ſet under the muffle in a cupelling furnace, and previouſly heated quite red. As ſoon as the metals are in the cupel raiſe the fire conſiderably, making uſe, if it be needful, of a pair of perpetual bellows, to melt the Copper ſpeedily. When it is thoroughly melted lower the fire a little, and continue it juſt high enough to keep the metalline maſs in perfect fuſion. The melted matter will then boil, and throw up ſome *ſcoriæ*, which will be abſorbed by the cupel.

When moſt of the Lead is conſumed, raiſe the fire again till the face of the Copper become bright and ſhining, thereby ſhewing that all its alloy is ſeparated. As ſoon as your Copper comes to this ſtate, cover it with charcoal-duſt conveyed into the cupel with an iron ladle: then take the cupel out of the furnace and let it cool.

OBSERVATIONS.

OF all the metals, next to Gold and Silver, Copper bears fuſion the longeſt without loſing its phlogiſton; and on this property is founded the proceſs here delivered for purifying it.

It is neceſſary the Copper ſhould melt as ſoon as it is in the cupel, becauſe its nature is to calcine much more eaſily and much ſooner, when it is only red-hot, than when it is in fuſion. For this reaſon the fire is to be conſiderably raiſed, immediately on putting the Copper under the muffle, that it may melt as ſoon as poſſible. Yet too violent a degree of fire muſt not be applied to it; for when it is expoſed to ſuch a degree of heat only as is but juſt neceſſary to keep it in fuſion, it is then in the moſt favourable condition for loſing as little as may be of its phlogiſton; and if the heat be ſtronger, a greater quantity thereof will be calcined. As ſoon therefore as it flows it is proper to weaken the fire, and reduce it to the degree juſt requiſite to keep up the fuſion.

The Lead added on this occaſion is intended to facilitate and expedite the ſcorification of the metallic ſubſtances combined with the Copper. So that the event is here nearly the ſame as when Gold or Silver is refined on the cupel. The only difference between this refining of Copper, and that of the perfect metals, is that the latter, as hath been ſhewn, abſolutely reſiſt the force of fire and the action of Lead, without ſuffering the leaſt alteration; whereas a good deal of Copper is calcined and deſtroyed, when it is purified in this manner on the cupel. Indeed it would be wholly deſtroyed, if a greater quantity of Lead were added, or if it were left too long in the furnace. It is with a view to ſave as much of it as poſſible that we order it to be covered with charcoal-duſt as ſoon as the ſcorification is finiſhed.

The Lead ſerves moreover to free the Copper expeditiouſly from the Iron with which it may be alloyed. Iron and Lead are incapable of contracting any union together: ſo that as faſt as the Lead unites with the Copper, it ſeparates the Iron, and excludes it out of the mixture. For the ſame reaſon if Iron were combined in a large proportion with Copper, it would prevent the Lead from entering into the compoſition. Now, as it is neceſſary to give the more heat, and to keep the Copper to be incorporated with Lead the longer in fuſion, as that Copper is alloyed with a greater proportion of Iron, ſome black flux muſt be added on this occaſion, to prevent the Copper and the Lead from being calcined before their aſſociation can be effected.

Copper purified in the manner here directed is beautiful and malleable. It is now alloyed with no other metalline ſubſtance but Gold or Silver, if there were any in the mixed maſs. If you deſire to extract this Gold or Silver, recourſe muſt be had to the operation of the cupel. The proceſs here given for purifying Copper is not uſed in large works, becauſe it would be much too chargeable. In order to purify their Black Copper, and render it malleable, the ſmelters content themſelves with roaſting it, and melting it repeatedly, that the metallic ſubſtances which are not ſo fixed as copper may be diſſipated by ſublimation, and the reſt ſcorified by fuſion.

PROCESS III.

To deprive Copper of its Phlogiſton by calcination.

PUT your Copper in filings into a teſt, and ſet it under the muffle of a cupelling furnace; light the fire, and keep up ſuch a degree of heat as may make the whole quite red, but not enough to melt the Copper. The ſurface of the Copper will gradually loſe its metalline ſplendour, and put on the appearance of a reddiſh earth. From time to time ſtir the filings with a little rod of copper or iron, and leave your metal expoſed to the ſame degree of fire till it be entirely calcined.

OBSERVATIONS.

IN our obſervations on the preceding proceſs we took notice that Copper, in fuſion, calcines more ſlowly, and leſs eaſily, than when it is expoſed to a degree of fire barely ſufficient to keep it red-hot, without melting it; and therefore, the deſign here being to calcine it, we have directed that degree of heat only to be applied.

The cupelling furnace is the fitteſt for this operation, becauſe the muffle is capable of receiving ſuch a flat veſſel as ought to be uſed on this occaſion, and communicating to it a great deal of heat; while, at the ſame time, it prevents the falling in of any coals, which, by furniſhing the Copper with freſh phlogiſton, would greatly prejudice and protract the operation.

As Copper calcines with great difficulty, this operation is extremely tedious: nay, though Copper hath ſtood thus expoſed to the fire for ſeveral days and nights, and ſeems perfectly calcined, yet it frequently happens that when you try afterwards to melt it, ſome of it reſumes the form of Copper: a proof that all the Copper had not loſt its phlogiſton. Copper is much more expeditiouſly deprived of its phlogiſton by calcining it in a crucible with Nitre.

The calx of Copper perfectly calcined is with great difficulty brought to fuſion: yet, in the focus of a large burning glaſs, it melts and turns to a reddiſh and almoſt opaque glaſs.

By the proceſs here delivered you may likewiſe calcine all other metalline ſubſtances which do not melt till they be thoroughly red-hot. As to thoſe which melt before they grow red, they are eaſily enough calcined, even while they are in fuſion.

PROCESS IV.

To reſuſcitate the Calx of Copper, and reduce it to Copper, by reſtoring its Phlogiſton.

MIX the Calx of Copper with thrice as much of the black flux; put the mixture into a good crucible, ſo as to fill two thirds thereof, and over it put a layer of Sea-ſalt a finger thick. Cover the crucible, and ſet it in a melting furnace; heat it gradually, and keep it moderately red till the decrepitation of the Sea-ſalt be over. Then raiſe the fire conſiderably by means of a good pair of perpetual bellows; ſatisfy your ſelf that the matter is in perfect fuſion, by dipping into the crucible an iron wire; continue the fire in this degree for half a quarter of an hour. When the crucible is cold, you will find at its bottom a button of very fine Copper, which will eaſily ſeparate from the ſaline ſcoria at top.

OBSERVATIONS.

WHAT hath been ſaid before on the ſmelting of Copper ores may be applied to this proceſs, as being the very ſame. The obſervations there added ſhould therefore be conſulted on this occaſion.

PROCESS V.

To diſſolve Copper in the Mineral Acids.

ON a ſand-bath, in a very gentle heat, ſet a matraſs containing ſome Copper filings; pour on them twice their weight of Oil of Vitriol. That Acid will preſently attack the Copper. Vapours will riſe, and iſſue out of the neck of the matraſs. A vaſt number of bubbles will aſcend from the ſurface of the metal to the top of the liquor, and the liquor will acquire a beautiful blue colour. When the Copper is diſſolved, put in a little and a little more, till you perceive the Acid no longer acts upon it. Then decant the liquor, and let it ſtand quiet in a cool place. In a ſhort time great numbers of beautiful blue cryſtals will ſhoot in it. Theſe cryſtals are called *Vitriol of Copper*, or *Blue Vitriol*. They diſſolve eaſily in Water.

OBSERVATIONS.

THE Vitriolic Acid perfectly diſſolves Copper, which is alſo ſoluble in all the Acids, and even in many other menſtruums.

This Acid may be ſeparated from the Copper which it hath diſſolved by diſtillation only: but the operation requires a fire of the utmoſt violence. The Copper remaining after it muſt be fuſed with the black flux, to make it appear in its natural form; not only becauſe it ſtill retains a portion of the Acid, but alſo becauſe it hath loſt part of its phlogiſton by being diſſolved therein. The black flux is very well adapted both to abſorb the Acid that remains united with the Copper, and to reſtore the phlogiſton which the metal hath loſt.

The moſt uſual method of ſeparating Copper from the Vitriolic Acid is by preſenting to that Acid a metal with which it hath a greater affinity than with Copper. Iron being ſo qualified is conſequently very fit to bring about this ſeparation. When therefore plates of Iron well cleaned are laid in a ſolution of Blue Vitriol, the Acid ſoon begins to act upon them, and by degrees, as it diſſolves them, depoſites on their ſurfaces a quantity of Copper in proportion to the quantity of Iron it takes up. The Copper thus precipitated hath the appearance of ſmall leaves or ſcales, exceeding thin, and of a beautiful copper-colour. Care muſt be taken to ſhake the Iron-plates now and then, to make the ſcales of Copper fall off, which will otherwiſe cover them entirely, hinder the vitriolic Acid from attacking the Iron, and ſo put a ſtop to the precipitation of the remaining Copper.

When theſe ſcales of Copper ceaſe to ſettle on the clean Iron plates, you may be ſure all the Copper that was in the liquor is precipitated, and that this liquor, which was a ſolution of Copper before the precipitation, is a ſolution of Iron after it. So that here two operations are performed at one and the ſame time; to wit, the precipitation of the Copper, and the diſſolution of the Iron.

The Copper thus precipitated requires only to be ſeparated from the liquor by filtration, and melted with a little black flux, to become very fine malleable Copper.

The Copper may alſo be precipitated out of a ſolution of Blue Vitriol by the interpoſition of a Fixed Alkali. This precipitate is of a greeniſh blue colour, and requires a much greater quantity of the black flux to reduce it.

Copper diſſolves in the Nitrous Acid, in the Marine Acid, and in *Aqua Regis*; from all of which it may be ſeparated by the ſame methods as are here ordered with regard to the Vitriolic Acid.

CHAP. IV.

Of IRON.

PROCESS I.

To ſeparate Iron from its Ore.

POUND into a coarſe powder the martial ſtones or earths out of which you deſign to extract the Iron: roaſt this powder in a teſt under the muffle for ſome minutes, and let your fire be briſk. Then let it cool, beat it very fine, and roaſt it a ſecond time, keeping it under the muffle till it emit no more ſmell.

Then mix with this powder a flux compoſed of three parts of Nitre fixed with Tartar, one part of fuſile glaſs, and half a part of Borax and charcoal-duſt. The doſe of this reducing flux muſt be thrice the weight of the ore.

Put this mixture into a good crucible; cover it with about half a finger thick of Sea-ſalt; over the crucible put its cover, and lute it on with Windſor-loam made into a paſte with water. Having thus prepared your crucible, ſet it in a melting furnace, which you muſt fill up with charcoal. Light the fire, and let it kindle by gentle degrees, till the crucible become red-hot. When the decrepitation of the ſea-ſalt is over, raiſe your fire to the higheſt by the blaſt of a pair of perpetual bellows, or rather ſeveral. Keep up this intenſe degree of heat for three quarters of an hour, or a whole hour, taking care that during all this time the furnace be kept conſtantly filling up with freſh coals as the former conſume. Then take your crucible out of the furnace; ſtrike the pavement on which you ſet it ſeveral times with a hammer, and let it ſtand to cool: break it, and you will find therein a Regulus of Iron covered with ſlag.

OBSERVATIONS.

IRON ore, like all others, requires roaſting, to ſeparate from it, as much as poſſible, the volatile minerals, Sulphur and Arſenic, which being mixed with the Iron would render it unmalleable. Indeed it is ſo much the more neceſſary to roaſt theſe ores, as Iron is, of all metallic ſubſtances, that which has the greateſt affinity with thoſe volatile minerals; on which account no metallic ſubſtance whatever is capable of ſeparating it from them by fuſion and precipitation.

Fixed Alkalis, it is true, have a greater affinity than Iron with Sulphur; but then the compoſition which a Fixed Alkali forms with Sulphur is capable of diſſolving all metals. Conſequently, if you do not diſſipate the Sulphur by roaſting, but attempt to ſeparate it from the Iron by melting the ore with a Fixed Alkali, the Liver of Sulphur formed in the operation will diſſolve the martial part; ſo that after the fuſion you will find little or no Regulus.

All Iron ores in general are refractory, and leſs fuſible than any other; for which reaſon a much greater proportion of flux, and a much more violent degree of fire, is required to ſmelt them. One principal cauſe why theſe ores are ſo refractory is the property which Iron itſelf has of being extremely difficult to fuſe, and of reſiſting the action of the fire ſo much the more as it is purer, and further removed from its mineral ſtate. Among all the metallic ſubſtances it is the only one that is leſs fuſible when combined with that portion of phlogiſton which gives it the metalline form, than when it is deprived thereof, and in the form of a calx.

In ſmelting houſes Iron ore is fuſed amidſt charcoal, the phlogiſton of which combines with the martial earth, and gives it the metalline form. The Iron thus melted runs down to the bottom of the furnace, from whence it is let out into large moulds, in which it takes the ſhape of oblong blocks, called *Pigs* of Iron. This Iron is ſtill very impure, and quite unmalleable. Its want of ductility after the firſt melting ariſes partly from hence, that, notwithſtanding the previous roaſting which the ore underwent, there ſtill remains, after this firſt fuſion, a conſiderable quantity of Sulphur or Arſenic combined with the metal.

A certain quantity of quick-lime, or of ſtones that will burn to lime, is frequently mixed with Iron ore on putting it into the ſmelting furnace. The lime being an abſorbent earth, very apt to unite with Sulphur and Arſenic, is of uſe to ſeparate thoſe minerals from the Iron.

It is alſo of uſe to mix ſome ſuch matters with the ore, when the ſtones or earths which naturally accompany it are very fuſible; for, as the Iron is of difficult fuſion, it may happen that the earthy matters mixed with the Iron ſhall melt as eaſily as the metal, or perhaps more eaſily. In ſuch a caſe there is no ſeparation of the earthy from the metalline part, both of which melt and precipitate together promiſcuouſly: now quick-lime, being extremely refractory, ſerves on this occaſion to check the melting of thoſe matters which are too fuſible.

Yet quick-lime, notwithſtanding its refractory quality, may ſometimes be of uſe as a flux for Iron: this is the caſe when the ore happens to be combined with ſubſtances which, being united with lime, render it fuſible: ſuch are all arſenical matters, and even ſome earthy matters, which being combined with quick-lime make a fuſible compound.

When the ore of an Iron mine is found difficult to reduce, it is uſually neglected even though it be rich; becauſe Iron being very common, people chuſe to work thoſe mines only whoſe ores are ſmelted with the moſt eaſe, and require the leaſt conſumption of wood.

Yet refractory ores are not to be altogether rejected, when another Iron ore of a different quality is found near them. For it often happens that two ſeveral Iron ores, which being worked ſeparately are very difficult to manage, and yield at laſt but bad Iron, become very tractable, and yield excellent Iron, when ſmelted together: and accordingly ſuch mixtures are often made at Iron-works.

The Iron obtained from ores by the firſt fuſion may be divided into two ſorts. The one, when cold, reſiſts the hammer, doth not eaſily break, and is in ſome meaſure extenſible on the anvil; but if ſtruck with a hammer when red-hot flies into many pieces: this ſort of Iron hath always a mixture of Sulphur in it. The other ſort, on the contrary, is brittle when cold, but ſomewhat ductile when red-hot. This iron is not ſulphurated, is naturally of a good quality, and its brittleneſs ariſes from its metalline parts not being ſufficiently compacted together.

Iron abounds ſo much, and is ſo univerſally diffuſed through the earth, that it is difficult to find a body in which there is none at all: and this hath led ſeveral Chymiſts, even men of great fame, into the error of thinking that they had tranſmuted into Iron ſeveral ſorts of earths in which they ſuſpected no Iron, by combining them with an inflammable matter; whereas, in fact, all they did was to give the metalline form to a true martial earth which happened to be mixed with other earths.

PRO-

PROCESS II.

To render Pig-iron and brittle Iron malleable.

INTO an earthen veſſel widening upwards put ſome charcoal-duſt, and thereon lay the Pig-iron which you propoſe to render ductile; cover it all over with a quantity of charcoal; excite the fire violently with a pair, or more, of perpetual bellows till the Iron melt. If it do not readily flow and form a great deal of ſlag on its ſurface, add ſome flux, ſuch as a very fuſible ſand.

When the matter is in fuſion keep ſtirring it from time to time, that all the parts thereof may be equally acted on by the air and the fire. On the ſurface of the melted Iron *ſcoriæ* will be formed, which muſt be taken off as they appear. At the ſame time you will ſee a great many ſparkles darted up from the ſurface of the metal, which will form a ſort of fiery ſhower. By degrees, as the Iron grows purer, the number of theſe ſparkles diminiſhes, though they never vaniſh entirely. When but few ſparkles appear, remove the coals which cover the Iron, and let the ſlag run out of the veſſel; whereupon the metal will grow ſolid in a moment. Take it out while it is ſtill red-hot, and give it a few ſtrokes with a hammer, to try if it be ductile. If it be not yet malleable, repeat the operation a ſecond time, in the ſame manner as before. Laſtly, when it is thus ſufficiently purified by the fire, work it for a long time on the anvil, extending it different ways, and making it red-hot as often as there is occaſion. Iron thus brought to the neceſſary degree of ductility, ſo as to yield to the hammer, and ſuffer itſelf to be extended every way, either hot or cold, without breaking to bits, or even cracking in the leaſt, is very good and very pure. If it cannot be brought to this degree by the method here preſcribed, it is a proof that the ore from which this Iron was extracted ought to be mixed with other ores; but it frequently requires a great number of trials to obtain an exact knowledge of the quality and proportion of thoſe other ores with which it is to be mixed.

OBSERVATIONS.

THE brittleneſs and ſhortneſs of Pig-iron ariſes from the heterogeneous parts which it contains, and which could not be ſeparated from it by the firſt fuſion. Theſe extraneous matters are uſually Sulphur, Arſenic, an unmetallic earth, and alſo a ferruginous earth; but ſuch as could not be combined with the phlogiſton as it ought to be, in order to have the properties of a metal, and muſt therefore be conſidered as heterogeneous with reſpect to the other well conditioned martial particles.

The Pig-iron, by undergoing repeated fuſions, is freed from theſe heterogeneous matters; thoſe which are volatile, ſuch as Sulphur and Arſenic, being diſſipated, and the unmetallic matters being ſcorified. As to the ferruginous earth which did not at firſt acquire the metalline form, it becomes true Iron at laſt; becauſe, among the coals with which it is encompaſſed, it meets with a ſufficient quantity of phlogiſton to reduce it to metal. Charcoal is alſo neceſſary on this occaſion, that it may continually furniſh phlogiſton to the Iron, which would otherways be converted into a calx.

Hammering the red-hot Iron, after each fuſion, ſerves to force out from amongſt the martial parts ſuch earthy matters as may happen to remain there, and ſo to bring into cloſer contact the metalline parts which were ſeparated before by the interpoſition of thoſe heterogeneous matters.

PROCESS III.

To convert Iron into Steel.

TAKE ſmall bars of the beſt Iron; that is, of ſuch as is malleable both hot and cold; ſet them on their ends in a cylindrical earthen veſſel, whoſe depth is equal to the length of the bars, and in ſuch a manner that they may be an inch diſtant from each other, and from the ſides of the crucible. Fill the veſſel with a cement compounded of two parts of charcoal, one part of bones burnt in a cloſe veſſel till they become very black, and one half part of the aſhes of green wood; having firſt pulverized and thoroughly mixed the whole together. Take care to lift up the Iron bars a little, to the end that the cement may cover the bottom of the veſſel, and ſo that there be about the depth of half an inch thereof under every bar: cover the crucible and lute on the cover.

Set the crucible thus prepared in a furnace, ſo contrived that the crucible may be ſurrounded with coals from top to bottom: for eight or ten hours keep up ſuch a degree of fire that the veſſel may be moderately red; after this take it out of the furnace; plunge your little Iron bars into cold water, and you will find them converted into Steel.

OBSERVATIONS.

THE principal difference between Iron and Steel conſiſts in this, that the latter is combined with a greater quantity of phlogiſton than the former.

It appears by this experiment that, to make Iron unite with an inflammable matter, it is not neceſſary it ſhould be in fuſion; it is ſufficient that it be ſo red-hot as to be opened and ſoftened by the fire.

Every kind of charcoal is fit to be an ingredient in the compoſition of the cement employed to make Steel, provided it contain no vitriolic Acid. However, it hath been obſerved that animal coals produce a ſpeedier effect than others: for which reaſon it is proper to mix ſomething of that kind with charcoal-duſt, as above directed.

The following ſigns ſhew that the operation hath ſucceeded, and that the Iron is changed into good Steel.

This metal being quenched in cold water as propoſed above, acquires ſuch an extraordinary degree of hardneſs, that it will by no means yield to any impreſſion of the file or hammer, and will ſooner break in pieces than ſtretch upon the anvil. And here it is proper to obſerve, that the hardneſs of Steel varies with the manner in which it is quenched. The general rule is, that the hotter the Steel is when quenched, and the colder the water is in which you quench it, the harder it becomes. It may be deprived of the temper thus acquired, by making it red-hot, and letting it cool ſlowly; for it is thereby ſoftened, rendered malleable, and the file will bite upon it. For this reaſon the artiſans who work in Steel begin with untempering it, that they may with more eaſe ſhape it into the tool they intend to make. They afterwards new-temper the tool when finiſhed, and by this ſecond temper the Steel recovers the ſame degree of hardneſs it had acquired by the firſt temper.

The colour of Steel is not ſo white as that of Iron, but darker, and the grains, facets, or fibres, which appear on breaking it, are finer than thoſe obſerved in Iron.

If the bars of Iron thus cemented in order to convert them into Steel be too thick, or not kept long enough in cementation, they will not be turned into Steel throughout their whole thickneſs: their ſurfaces only will be Steel to a certain depth, and the center will be mere Iron; becauſe the Phlogiſton will not have thoroughly penetrated them. On breaking a bar of this ſort, the difference in colour and grain between the Steel and the Iron is very viſible.

It is eaſy to deprive Steel of the ſuperabundant quantity of Phlogiſton which conſtitutes it Steel, and thereby reduce it to Iron. For this purpoſe it need only be kept red-hot ſome time, obſerving that no matter approach it all the while that is capable of refunding to it the Phlogiſton which the fire carries off. The ſame end is ſtill ſooner obtained by cementing it with meagre hungry matters, capable of abſorbing the Phlogiſton; ſuch as bones calcined to whiteneſs, and cretaceous earths.

Steel may alſo be made by fuſion; or Pig-iron may be converted into Steel. For this purpoſe the ſame method muſt be employed as was above directed for reducing Pig-iron into malleable Iron; with this difference, that, as Steel requires more Phlogiſton than is neceſſary to Iron, all the means muſt be made uſe of that are capable of introducing into the Iron a great deal of Phlogiſton; ſuch as melting but a ſmall quantity of Iron at a time, and keeping it conſtantly encompaſſed with abundance of charcoal; re-iterating the fuſions; taking care that the blaſt of the bellows directed along the ſurface of the metal do not remove the coals that cover it, &c. And here it muſt be obſerved, that there are ſome ſorts of Pig-iron which it is very difficult to convert into Steel by this method, and that there are others which ſucceed very readily, and with ſcarce any trouble at all. The ores which yield the laſt mentioned ſort of Pig-iron are called *Steel Ores*. Steel made by this means muſt be tempered in the ſame manner as that made by cementation *.

PROCESS IV.

The Calcination of Iron. Sundry Saffrons of Mars.

TAKE filings of Iron, what quantity you pleaſe; put them into a broad unglazed earthen veſſel, ſet under the muffle of a cupelling furnace: make it red-hot; ſtir the filings frequently; and keep up the ſame degree of fire till the Iron be wholly turned into a red powder.

OBSERVATIONS.

IRON eaſily loſes its phlogiſton by the action of fire. The calx that remains after its calcination is exceeding red; which makes this be thought the natural colour of the earth of that metal. It hath accordingly been obſerved that all the earths and ſtones, which either are naturally red, or acquire that colour by calcination, are ferruginous.

The yellowiſh red colour which every calx of Iron hath, in whatever manner it be prepared, hath procured the name of *Crocus* or *Saffron* to every preparation of this kind. That made in the manner above directed is called in Medicine *Crocus Martis aſtringens*.

The ruſt produced on the ſurface of Iron is a ſort of calx of Iron made by the way of diſſolution.

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* Mr. Réaumur hath obliged the publick with a treatiſe on the means of converting Iron into Steel, in which he hath exhauſted the ſubject. Such as deſire the ampleſt and moſt uſeful inſtructions, on that part of metallurgy, would do well to conſult his Work.

The moiſture of the air acts upon the metal, diſſolves it, and robs it of ſome of its phlogiſton. This ruſt is called in Medicine *Crocus Martis Aperiens*; becauſe it is thought that the ſaline parts, by means whereof the humidity diſſolves the Iron, remain united with the metal after its diſſolution, and give it an aperitive virtue. The Apothecaries prepare this ſort of Saffron of Mars by expoſing Iron filings to the dew till they be turned entirely to ruſt; which is then called *Saffron of Mars by dew.*

Another Saffron of Mars is alſo prepared in a much ſhorter manner, by mixing filings of Iron with pulverized Sulphur and moiſtening the mixture, which after ſome time ferments and grows hot. It is then ſet on the fire; the Sulphur burns away, and the maſs is kept ſtirring till it become a red matter. This Saffron is nothing but Iron diſſolved by the Acid of Sulphur, which is known to be of the ſame nature with that of Vitriol; and conſequently this Saffron of Mars is no way different from Vitriol calcined to redneſs.

PROCESS V.

Iron diſſolved by the mineral Acids.

PUT any mineral Acid whatever into a matraſs with ſome water; ſet the matraſs on a ſand-bath gently heated; drop into the veſſel ſome filings of Iron: the phenomena which uſually accompany metalline diſſolutions will immediately appear. Add more filings, till you obſerve the Acid hath loſt all ſenſible action upon them: then remove your matraſs from the ſand-bath; you will find in it a ſolution of Iron.

OBSERVATIONS.

IRON is very eaſily diſſolved by all the Acids. If you make uſe of the Vitriolic Acid, care muſt be taken to weaken it with water in caſe it be concentrated; becauſe the diſſolution will ſucceed the better. The vapours that riſe on this occaſion are inflammable; and if a lighted paper be held to the mouth of the matraſs, eſpecially after keeping it ſtopt for ſome time and ſhaking the whole gently, the ſulphureous vapours take fire with ſuch rapidity as to produce a conſiderable exploſion; which is ſometimes ſtrong enough to burſt the veſſel into a thouſand pieces. This ſolution hath a green colour, and is in fact a fluid Green Vitriol, which wants nothing but reſt to make it ſhoot into cryſtals.

If you make uſe of the Nitrous Acid, you muſt ceaſe adding more filings when the liquor, after ſtanding ſtill ſome moments, becomes turbid; for, when this Acid is impregnated with Iron to a certain degree, it lets fall ſome of that which it had diſſolved, and becomes capable of taking up freſh filings. Thus by conſtantly adding new ſupplies of Iron, this Acid may be made to diſſolve a much greater quantity thereof than is neceſſary to ſaturate it entirely. This ſolution is of a ruſſet colour, and doth not cryſtallize.

If the weather be not extremely cold, and the Acids have a proper degree of ſtrength, the ſand-bath is unneceſſary, as the diſſolution will ſucceed very well without it.

Iron diſſolved by Acids may be ſeparated therefrom, like all other metallic ſubſtances in the ſame circumſtances, either by the action of fire, which carries off the Acid and leaves the Martial earth, or by the interpoſition of ſubſtances which have a greater affinity than metallic ſubſtances have with Acids; that is, by Abſorbent Earths and Alkaline Salts. By whatever means you ſeparate Iron from an Acid ſolvent, it conſtantly appears, after the ſeparation, in the form of a yellowiſh red powder; becauſe it is then deprived of moſt of the phlogiſton to which it owed its metalline form: whence it is reaſonable to think that this is the proper colour of Martial earth.

All theſe precipitates of Iron are true Saffrons of Mars, which, as well as thoſe prepared by calcination, are ſo much the further removed from the nature of a metal, the more they are deprived of their phlogiſton. Thence it comes that they are more or leſs ſoluble by Acids, and more or leſs attracted by the magnet: as no ferruginous earth, perfectly deprived of all inflammable matter, is at all attracted by the magnet, or ſoluble by Acids.

CHAP. V.

Of TIN.

PROCESS I.

To extract Tin from its Ore.

BREAK your Tin ore into a coarſe powder, and by waſhing carefully ſeparate from it all the heterogeneous matters and ores of a different kind that may be mixed therewith. Then dry it, and roaſt it in a ſtrong degree of fire, till no more Arſenical vapour riſe from it. When the ore is roaſted, reduce it to a fine powder, and mix it thoroughly with twice its weight of the black flux well dried, a fourth part of its weight of clean iron filings, together with as much borax and pitch: put the mixture into a crucible; over all put Sea-ſalt to the thickneſs of four fingers, and cover the crucible cloſe.

Set the crucible thus prepared in a melting furnace; apply at firſt a moderate and ſlow degree of fire, till the flame of the pitch, which will eſcape through the joint of the cover, diſappear entirely. Then ſuddenly raiſe your fire, and urge it with rapidity to the degree neceſſary for melting the whole mixture. As ſoon as the whole is in fuſion take the crucible out of the furnace, and ſeparate the Regulus from the ſcoria.

OBSERVATIONS.

ALL Tin ores contain a conſiderable quantity of Arſenic, and no Sulphur at all, or at moſt very little. Hence it comes that, though Tin be the lighteſt of all metals, its ore is nevertheleſs much heavier than any other; Arſenic being much heavier than Sulphur, of which the ores of every other kind always contain a pretty large proportion. This ore is moreover very hard, and is not brought to a fine powder with ſo much eaſe as the reſt.

Theſe properties of Tin ore furniſh us with the means of ſeparating it eaſily by lotion, not only from earthy and ſtony parts, but even from the other ores which may be mixed with it. And this is of the greater advantage on two accounts, viz. becauſe Tin cannot endure, without the deſtruction of a great part thereof, the degree of fire neceſſary to ſcorify the refractory matters which accompany its ore; and again becauſe this metal unites ſo eaſily with Iron and Copper, the ores of which are pretty commonly blended with Tin ore, that after the reduction it would be found adulterated with a mixture of theſe two metals, if they were not ſeparated from it before the fuſion.

But ſometimes the Iron ore confounded with that of Tin is very heavy, and is not eaſily pulverized;

whence it comes to paſs that it cannot be ſeparated therefrom by waſhing only. In that caſe the magnet muſt be employed to ſeparate it, after the ore hath been roaſted.

Roaſting is moreover neceſſary for Tin ore, in order to diſſipate the Arſenic which volatilizes, calcines, or deſtroys one part of the Tin, and reduces the reſt to a ſhort, brittle ſubſtance, like a Semi-metal. The ore is known to be ſufficiently roaſted when no more fumes riſe from it; when it has loſt the ſmell of garlick; and when it does not whiten a clean plate of Iron held over it.

Tin being one of thoſe metals which are moſt eaſily calcined, it is neceſſary in reducing its ore to employ ſuch matters as may furniſh it with phlogiſton. In order to defend it from the contact of the air, which always accelerates the calcination of metallic ſubſtances, the mixture is to be covered with Sea-ſalt; and the addition of pitch helps to increaſe the quantity of phlogiſton.

PROCESS II.

The Calcination of Tin.

INTO an unvarniſhed earthen diſh put the quantity of Tin you intend to calcine; melt it, and keep ſtirring it from time to time. Its ſurface will be covered with a greyiſh white powder: continue the calcination till all your Tin be converted into ſuch a powder, which is the *Calx of Tin.*

OBSERVATIONS.

THOUGH the calcination of metalline ſubſtances is promoted by expoſing them, in powder, or in filings, to the action of fire, and by ordering it ſo that they may not melt, becauſe they preſent a much ſmaller ſurface when melted than when unmelted;

yet we have not directed this precaution to be uſed in calcining Tin. The reaſon is, this metal is ſo fuſible that it cannot endure the degree of fire requiſite to deſtroy its phlogiſton without melting; and of courſe, though Tin calcines eaſily, the operation would nevertheleſs be tedious, becauſe the melted metal would preſent but a ſmall ſurface to be acted on by the fire and the air. This inconvenience may be partly remedied, and the operation greatly expedited, by dividing the quantity of Tin to be calcined into ſeveral ſmall parcels, and expoſing them to the fire in ſeparate veſſels, ſo that they may not re-unite when melted, and form one ſingle maſs.

Leaf Tin caſt on Nitre in actual fuſion cauſes it to deflagrate and fulminate; and from this mixture there riſes a white vapour, which is converted into flowers when it meets with any obſtacle to impede its flying off entirely.

Mr Geoffroy, who went through a courſe of experiments on Tin, an account whereof may be ſeen in the Memoirs of the Academy of Sciences, found that from the colour of the calx of that metal a judgment may be formed of its degree of purity, and nearly of the quantity and quality of the metallic ſubſtances with which it is alloyed. The experiments tried on this ſubject by that eminent Chymiſt are very curious.

He performed the calcination in a crucible, which he heated to a cherry-red, and kept up the ſame degree of fire from the beginning to the end of the operation. The calx which formed upon his metal, in that degree of heat, appeared like ſmall white ſcales, a little reddiſh on the under ſide. He puſhed it to one ſide as it formed, to the end that it might not cover the ſurface of the metal, which, like all others, requires the contact of the air to turn it into a calx.

"While he was making theſe calcinations, he had "an opportunity of obſerving a curious fact, of "which no body before him had ever taken notice; "probably becauſe no body had ever calcined Tin "by the ſame method. The fact is, that during "the calcination of the Tin, whether you break the "pellicle which forms on the ſurface of the metal "while in red-hot fuſion, or whether you let it re-"main without touching it, you perceive in ſeveral "places a ſmall ſwell of a certain matter which burſts "and makes its way through the pellicle. This "matter puffs up, grows red, at the ſame inſtant "takes fire, and darts out a ſmall whitiſh flame, "as vivid and as brilliant as that of Zinc when "urged by a fire ſtrong enough to ſublime it into "flowers. The vividneſs of this flame may be fur-"ther compared to that of ſeveral ſmall grains of "phoſphorus of urine fired and gently dropped on "boiling water. From this bright flame a white "vapour exhales; after which the ſwelled maſs "partly crumbles down, and turns to a light white "powder, ſometimes ſpotted with red, according "to the force of the fire. After this momentary "ignition, there ariſe ſtronger, more numerous, or "more frequent heavings of matter, out of which "iſſues a good deal of white fume, that may be in-"tercepted by a cover of tin-plate or copper fitted "to the crucible, and appears to be the flowers of "Tin, which in ſome meaſure corrode theſe metals. "Hence Mr. Geoffroy conjectures, with a great deal "of probability, that their ſublimation is promoted "by a portion of Arſenic. When the cruſt formed "by this calx comes to be too thick, or in too great "a quantity, to be puſhed on one ſide ſo as to leave "part of the metal uncovered, Mr. Geoffroy puts "out the fire, becauſe no more calx would be form-"ed; the communication of the external air with "the Tin in fuſion being abſolutely neceſſary there-

" to, as hath been already ſaid. In this operation " it is to be obſerved that, if the fire be too ſlow, " neither the inflammation of the ſulphureous parti" cles, nor the white fumes that riſe, will be ſo diſ" tinctly perceived, as when the fire is of the de" gree requiſite to keep the crucible juſt of a cher" ry-red heat.

" Mr. Geoffroy having taken off this firſt calx " began the calcination anew. In this ſecond heat " the buddings or heavings were more conſiderable, " and ſhot up in the form of cauli-flowers; but were " ſtill compoſed of little ſcales. The thoroughly cal" cined portion of this vegetation was likewiſe white " and red; and the inferiour ſurfaces of ſome little " bits thereof were wholly red. When theſe calci" nations are continued, ſulphureous vapours riſe " ſeemingly of another kind than thoſe which ap" peared in the beginning; for all the calx made " by the firſt heat was perfectly white; whereas in " the ſecond it begins to be ſpotted here and there " with a tinge of black. Mr. Geoffroy was obliged " to go through a courſe of twelve ſeveral calcina" tions before he could convert two ounces of Tin " into a calx. He had the opportunity, during " theſe ſeveral calcinations, to obſerve that after " the fourth, and ſometimes after the third, the " red ſpots of the calx decreaſe, and the black " increaſe; that the germinations ceaſe; that the " cruſt of the calx remains flat; that in the twelfth " fire the Tin yields no more of this ſcaly cruſt; " that towards the end the undulations of the fuſed " metal appear no longer; and that the ſmall re" mainder of calx is mixed with ſeveral very minute " grains of metal, which ſeem much harder than " Tin. Mr. Geoffroy could not collect a ſufficient " quantity thereof to cupel them, and ſatisfy him" ſelf whether or no they were Silver."

Though Tin, and all the imperfect metals in general, ſeem converted to a calx, and loſe the metalline form, by one ſingle calcination, and that a ſlight one; yet they are not wholly deprived of their phlogiſton: for if the calx of Tin, for inſtance, prepared according to the proceſs above delivered, be caſt upon Nitre in fuſion, it will make that ſalt deflagrate very perceptibly; a convincing proof that it ſtill contains much inflammable matter. If therefore a calx be required abſolutely free from phlogiſton, this firſt calx muſt be re-calcined by a more violent fire, and the calcination continued till all the phlogiſton be diſſipated.

" Mr. Geoffroy, being deſirous of having his calx " of Tin very pure and perfectly calcined, expoſed " once more to the action of fire the twelve portions " of calx obtained by his former calcinations. But, " as it would have been too tedious to re-calcine them " all ſeparately, he made four parcels of the whole, " each conſiſting of three taken according to the or- " der in which they were firſt calcined; and gave to " each a fire ſufficiently ſtrong, and long enough con- " tinued, to calcine them as thoroughly as was poſ- " ſible. After this ſecond calcination, he found them " all of a moſt beautiful white, except the firſt par- " cel: as that conſiſted of the portions obtained by " the three firſt heats, in all of which there were ſcales " tinged with red, it ſtill retained a ſtain of carnation, " though hardly perceptible. Agreeably to the ge- " neral rule, the two ounces of Tin gained in weight " by being thus calcined; and the increaſe was two " drams and fifty ſeven grains.

" Mr. Geoffroy obſerves that no Tin, but what " is abſolutely pure, will yield a perfectly white " calx. He calcined in this manner ſeveral other " parcels of Tin that were impure and variouſly al- " loyed; each of which produced a calx differently " coloured, according to the nature and quantity of "its alloy: whence he juſtly concludes that calci-"nation is a very good method of trying the fine-"neſs of Tin, or its degree of purity." The particulars of Mr. Geoffroy's experiments on this ſubject, which are very curious, may be ſeen in the Memoirs of the Academy for 1738.

It is proper to take notice that a man ſhould be very cautious how he expoſes himſelf to the vapours of Tin, becauſe they are dangerous; this metal being very juſtly ſuſpected by Chymiſts of containing ſomething Arſenical.

PROCESS III.

The diſſolution of Tin by Acids. The Smoking liquor of Libavius.

PUT into a glaſs veſſel what quantity you pleaſe of fine Tin cut into little bits. Pour on it thrice as much *Aqua Regis*, compounded of two parts *Aqua Fortis* weakened with an equal quantity of very pure water, and one part Spirit of Salt. An ebullition will ariſe, and the Tin will be very rapidly diſſolved; eſpecially if the quantities of metal and of *Aqua Regis* be conſiderable.

OBSERVATIONS.

TIN is ſoluble by all the Acids; but *Aqua Regis* diſſolves it beſt of any. Yet in this diſſolution it comes to paſs that part of the diſſolved Tin precipitates of its own accord to the bottom of the veſſel, in the form of a white powder. This ſolution of Tin is very fit for preparing the purple-coloured precipitate of Gold. For this purpoſe the ſolution of Tin muſt be let fall, drop by drop, into a ſolution of Gold. Spirit of Nitre diſſolves Tin nearly as *Aqua Regis* does; but it occaſions a greater quantity of calx.

If two or three parts of Oil of Vitriol be poured on one part of Tin, and if the veſſel in which the mixture is made be expoſed to ſuch a degree of heat as to evaporate all the moiſture, there will remain a tenacious matter ſticking to the ſides of the veſſel. If water be poured on this matter, and it be then expoſed a ſecond time to the fire, it will diſſolve entirely, excepting a ſmall portion of a glutinous ſubſtance, which alſo may be diſſolved in freſh Oil of Vitriol.

The Acid of Sea-ſalt may be combined with Tin by the following proceſs. Mix perfectly, by trituration in a marble mortar, an amalgam of two ounces of fine Tin, and two ounces and a half of Quick-ſilver, with as much Corroſive Sublimate. As ſoon as the mixture is completed, put it into a glaſs retort, and diſtill with the ſame precautions as we directed to be uſed in preparing concentrated and ſmoking Acids. There will firſt come over into the receiver ſome drops of a limpid liquor, which will be ſoon followed by an elaſtic ſpirit that will iſſue out with impetuoſity. At laſt ſome flowers, and a ſaline tenacious matter, will riſe into the neck of the retort. Then ſtop your diſtillation, and pour into a glaſs bottle the liquor you will find in the receiver. This liquor continually exhales a conſiderable quantity of denſe, white fumes, as long as it is allowed to have a free communication with the air.

The product of this diſtillation is a combination of the Acid of Sea-ſalt with Tin. As the affinity of Tin with this Acid is greater than that of Mercury, the Acid contained in the Corroſive Sublimate quits the Mercury, wherewith it was united, to join the Tin; which it volatilizes ſo as to make it riſe with itſelf in a liquid form. We make uſe of the amalgam of Tin with Quick-ſilver, becauſe we are thereby enabled to mix the Corroſive Sublimate perfectly therewith, as the ſucceſs of the operation requires it ſhould be.

In this experiment the Tin is volatilized, and the Acid of Sea-ſalt, which is exceedingly concentrated, flies off inceſſantly in the form of white vapours. This compound is known in Chymiſtry by the name of *the Smoking Liquor of Libavius*; a name derived from its quality, and from its Inventor. Tin diſſolved by Acids is eaſily ſeparated from them by Alkalis. It always precipitates in the form of a white calx.

CHAP. VI.

Of LEAD.

PROCESS I.

To extract Lead from its Ore.

HAVING roaſted your Lead ore reduce it to a fine powder; mix it with twice its weight of the black flux, and one fourth of its weight of clean iron filings and borax; put the whole into a crucible capable of containing at leaſt thrice as much; over all put Sea-ſalt four fingers thick; cover the crucible; lute the juncture; dry the whole with a gentle heat, and ſet it in a melting furnace.

Make the crucible moderately red: you will hear the Sea-ſalt decrepitate, and after the decrepitation a ſmall hiſſing in the crucible. Keep up the ſame degree of fire till that be over.

Then throw in as many coals as are neceſſary to complete the operation entirely, and raiſe the fire ſuddenly, ſo as to bring the whole mixture into perfect fuſion. Keep up this degree of fire for a quarter

ter of an hour, which is time ſufficient for the precipitation of the Regulus.

When the operation is finiſhed; which may be known by the quietneſs of the matter in the crucible, and by a bright vivid flame that will riſe from it, take the crucible out of the furnace, and ſeparate the Regulus from the ſcoria.

OBSERVATIONS.

ALL Lead ore contains a good deal of Sulphur, which muſt be firſt ſeparated from it by roaſting: and as this kind of ore is apt to fly when firſt expoſed to the fire, it is proper to keep it covered till it be thoroughly heated. Another precaution to be uſed, in roaſting this ore, is not to give it too great a heat, but to keep the veſſel which contains it juſt moderately red; becauſe it eaſily turns clammy, which occaſions it to ſtick to the veſſel.

The Iron that is added, and mixed with the flux, abſorbs the Sulphur which may happen to remain, even after roaſting: it helps alſo to ſeparate from the Lead ſome portions of ſemi-metal, eſpecially of Antimony, which are frequently mixed with this ore.

There is no fear leſt the Iron mix with the Lead in fuſion, and adulterate it: for theſe two metals are incapable of contracting any union together, when each has its metalline form.

Nor is there any reaſon to apprehend leſt the Iron ſhould, by its refractory quality, obſtruct the fuſion of the mixture; for though this metal be not fuſible when alone; yet, by the union it contracts with the matters it is deſigned to abſorb, it becomes ſo to ſuch a degree as in ſome meaſure to perform, on this occaſion, the office of a flux.

The government of the fire is a point of great conſequence in this operation. It is neceſſary to apply but a moderate degree of heat at firſt: for, when the metallic earth of the Lead, combining with the phlogiſton, acquires the metalline form, it ſwells up in ſuch an extraordinary manner, that there is great danger leſt the matter ſhould overflow and run all out of the containing veſſel. With a view therefore to avoid this inconvenience, we direct a very large crucible to be uſed. This heaving of the Lead at the inſtant of its reduction is attended with a noiſe like the whiſtling of wind.

Notwithſtanding all the precautions that can be uſed to prevent the reduction from taking place too haſtily, and ſo occaſioning the effuſion of the matter, it often happens that, on raiſing the fire in order to bring the mixture into fuſion, the hiſſing ſuddenly begins again, and is very loud. In that caſe all the apertures of the furnace muſt immediately be ſhut cloſe, in order to choak and ſuffocate the fire: for, if this be neglected, the matter in the crucible will ſwell up, make its way through the luting of the juncture, nay, puſh up the cover, and run over. This accident is to be apprehended during the firſt five or ſix minutes after you raiſe the fire in order to melt the mixture. This effuſion of the matter is accompanied with a dull flame, a thick, grey and yellow ſmoke, and a noiſe like that of ſome boiling liquor. When you obſerve theſe ſeveral phenomena you may be ſure the matter is run out of the crucible, either in the manner above deſcribed, or by making its way through ſome cracks in the veſſel, and conſequently that the operation is ſpoiled.

Moreover, this event infallibly follows whenever a bit of coal happens to fall into the crucible; and this is one reaſon why it is neceſſary to cover it.

You may be certain that the operation hath ſucceeded if the ſcoria is ſmooth when cold, and hath not in part eſcaped through the lute; if the Lead be not diſperſed in globules through the whole maſs of the matter contained in the crucible, but is, on the contrary, collected at the bottom in the form of a ſolid Regulus, not very ſhining, but of a blueiſh caſt, and ductile. Moreover the ſcoria ought, in the preſent caſe, to be hard and black, and ſhould not appear full of holes like a ſieve, except only in that part which was contiguous to the Salt.

Here it is proper to obſerve that the Sea-ſalt doth not mix with the ſcoria, but floats upon it. After the operation it is black; which colour it gets, no doubt, from the charred parts of the flux. The abſence of theſe ſigns ſhews the operation to have miſcarried. When the ore to be ſmelted is pyritoſe and refractory, it may be roaſted at firſt with a much ſtronger degree of fire than is uſed for ores that are fuſible; becauſe the martial earth, and the unmetallic earth, which are always mixed in pyritoſe matters, hinder it from growing readily ſoft in the fire.

Beſides, ſuch an ore requires a greater quantity of the black flux and of borax to be mixed with it, and a higher degree of fire to fuſe it.

It is generally needleſs to mix iron filings with this ſort of ore; becauſe the martial earth, with which pyritoſe matters are always accompanied, is reduced during the operation by the help of the black flux, which for that purpoſe is mixed with it in a large proportion, and furniſhes a quantity of iron ſufficient to abſorb the heterogeneous minerals mixed with the Lead.

Yet, if it ſhould be obſerved that the pyrites which accompany the Lead ore are arſenical, then, as ſuch pyrites contain but a ſmall quantity of ferruginous earth, iron filings muſt be added; which are, on this occaſion, ſo much the more neceſſary for abſorbing the Arſenic, as this mineral remains in part confounded with the ore, is reduced to a Regulus during the operation, unites with the Lead, and deſtroys a great deal of it by procuring its vitrification.

The Lead obtained from ſuch pyritoſe ores is commonly not very pure: it is blackiſh and ſcarce ductile; qualities communicated to it by a ſmall mixture of Copper in the pyrites, which always contain more or leſs thereof. We ſhall afterwards ſhew the method of ſeparating Lead from Copper.

Lead ore may alſo be reduced by melting it amidſt coals. For that purpoſe firſt kindle a fire in the furnace in which you intend to melt your ore; then put a layer of your ore immediately upon the lighted coals, and cover it with another layer of coals.

Though the melting furnace uſed for this operation be capable of giving a conſiderable heat, yet it is neceſſary further to encreaſe the force of the fire by the means of a good pair of perpetual bellows, which will produce an effect like that of a forge. The ore melts, the earth of the Lead unites with the phlogiſton of the coals; and ſo is reduced to metal, which runs through the coals, and falls into an earthen veſſel placed at the bottom of the furnace to receive it. Care muſt be taken to keep this veſſel well filled with charcoal-duſt, to the end that the Lead may be in no danger of calcination while it continues there; the charcoal-duſt conſtantly furniſhing it with phlogiſton to preſerve its metalline form.

The earthy and ſtony matters that accompany the ore are ſcorified by this fuſion, juſt as they are by the other which is performed in a cloſe veſſel. With regard to the Sulphur and Arſenic, they are ſuppoſed to have been firſt accurately ſeparated from the ore by roaſting. This is the method commonly employed for ſmelting Lead ore at the works.

PRO-

PROCESS II.

To ſeparate Lead from Copper.

WITH luting earth and charcoal-duſt make a flat veſſel, widening upwards, and large enough to contain your metalline maſs. Set it ſhelving downwards from the back towards the fore-part; and in the fore-part, at the bottom, make a little gutter communicating with another veſſel of the ſame nature, placed near the former and a little lower. Let the mouth of the gutter within ſide the upper veſſel be narrowed, by means of a ſmall iron plate fixed acroſs it, while the loam is yet ſoft; ſo as to leave a very ſmall aperture in the lower part of this canal ſufficient to diſcharge the Lead as it melts. Dry the whole by placing lighted coals round it.

When this apparatus is dry, put your mixed maſs of Copper and Lead into the upper veſſel: both in that, and in the other veſſel, light a very gentle fire of wood or charcoal, ſo as not to exceed the degree of heat neceſſary to melt Lead. In ſuch a degree of heat the Lead contained in the mixed maſs will melt, and you will ſee it run out of the upper veſſel into the lower; at the bottom of which it will unite into a Regulus. When in this degree of heat no more Lead flows, increaſe the fire a little, ſo as to make the veſſel moderately red.

When no more will run, collect the Lead contained in the lower veſſel. Melt it over again in an iron ladle, with a degree of fire ſufficient to make the ladle red; throw into it a little tallow or pitch, and while it burns keep ſtirring the metal, in order to reduce any part of it that may be calcined. Remove the pellicle or thin cruſt which will form on the ſurface; ſqueeze out all the Lead it contains, and then put it to the maſs of Copper left in the upper veſſel. Check the fire, and in the ſame manner take off a ſecond ſkin that will form on the ſurface of the Lead. Laſtly, when the metal is ready to fix, take off the ſkin that will then appear on it. The Lead remaining after this will be very pure, and free from all alloy of Copper.

With regard to the Copper itſelf, you will find it in the upper veſſel covered with a thin coat of Lead: and if the Lead mixed with it was in the proportion of a fourth or a fifth part only, and the fire applied was gentle and ſlow, it will retain nearly the ſame form after the operation that the mixed maſs had before.

OBSERVATIONS.

LEAD frequently remains mixed with Copper after the reduction of its ore, eſpecially if the ore was pyritoſe. Though Copper be a much more beautiful and more ductile metal than Lead; yet the latter by being alloyed with the former is rendered eager and brittle. This bad quality is eaſily diſcovered by the eye on breaking it: for the ſurface of the broken part appears all granulated; whereas when it is pure it is more evenly, and reſembles a congeries of ſolid angles. If the Lead be alloyed with a conſiderable quantity of Copper, its colour hath a yellowiſh caſt.

Conſidering the bad qualities which Copper communicates to Lead, it is neceſſary to ſeparate theſe two metals from each other. The method above laid down is the ſimpleſt and the beſt. It is founded on two properties belonging to Lead: the firſt is that of being much more fuſible than Copper; ſo that it will melt and run in a degree of heat that is not capable of making the Copper even red-hot, which yet is very far from being able to melt it: the ſecond is, that Lead, though it hath an affinity with Copper, and unites very perfectly therewith, yet is not able to diſſolve it without a greater heat than the degree barely neceſſary to fuſe Lead. Hence it comes that Lead may be melted in a Copper veſſel, provided no greater degree of heat be applied than that purpoſe requires. But when the Lead becomes ſo hot as to be red, fume, and boil, it inſtantly begins to diſſolve the Copper. For this reaſon, it is eſſential to the ſucceſs of our operation that a moderate degree of heat only be applied, and no greater than is requiſite to keep the Lead in fuſion.

Charcoal-duſt is made an ingredient in the compoſition of the veſſels uſed on this occaſion, in order to prevent the calcination of the Lead.

The iron plate, with which the entrance of the gutter within the upper veſſel is narrowed, ſerves to prevent the larger pieces of Copper, which the Lead may carry along with it, from paſſing through: it ſtops them, and allows the Lead to run off alone.

But as theſe parcels of Copper may entirely choak the paſſage, care muſt be taken, when any happen to be ſtopt, to remove them from the entrance of the gutter, and puſh them back into the middle of the veſſel. It is alſo neceſſary to obſerve whether or no the Lead fixes any where in the paſſage; and, if it does, the heat of that part muſt be encreaſed, in order to melt it and make it run off.

Notwithſtanding all the precautions that can be taken to hinder the melted Lead from carrying off any Copper with it, it is impoſſible to prevent this inconvenience entirely: and therefore the Lead is melted over again, in order to ſeparate the ſmall portion of Copper with which it is ſtill adulterated.

As Copper is much lighter than Lead, if theſe two metals happen to be ſo blended together that the Copper, without being in fuſion and diſſolved by the Lead, is only interpoſed between the parts of the melted Lead, ſo as to ſwim therein, it is then preciſely in the caſe of a ſolid body plunged into a fluid heavier than itſelf, and muſt riſe to the ſurface like wood thrown into water. It is proper to burn ſome inflammable matter on this melted Lead, in order to reduce ſuch parts thereof as are conſtantly calcining on its ſurface while it is in fuſion; for without this precaution they would be taken off together with the Copper.

The Copper remaining after this ſeparation is, as we took notice before, ſtill mixed with a little Lead. If you deſire to ſeparate it entirely therefrom, you muſt put it into a cupel, and expoſe it under the muffle to ſuch a degree of fire as may convert all the Lead into litharge. This cannot be ſo done but that ſome of the Copper alſo will be ſcorified by the heat of the fire, and by the action of the Lead: but as there is a very great difference between the facility and readineſs with which theſe two metals calcine, the portion of Copper that is calcined, while the whole Lead is turning into litharge, is ſcarce worth conſidering.

The Lead, though carefully ſeparated from the Copper by the proceſs here delivered, is not yet abſolutely pure: ſometimes it is alloyed with Gold, and almoſt always contains ſome Silver. If you would free the Lead as much as poſſible from any mixture of theſe two metals, you muſt convert it into glaſs, ſeparate the remaining bead, and afterwards reduce this glaſs of Lead. But, as theſe two perfect metals are of no prejudice to the Lead, it is not uſual to ſeparate them from it, unleſs they be in a ſufficient proportion to defray the charge, and produce ſome profit beſides.

When we examine by the cupel the juſt proportion of Gold and Silver that an ore or a mixed metalline maſs will yield, we make a previous aſſay of the Lead to be employed in the operation, and afterwards, in our eſtimate, deduct a proper allowance for the quantity of fine metal due to the Lead made uſe of.

PROCESS III.

The Calcination of Lead.

TAKE what quantity of Lead you pleaſe; melt it in one or more unglazed earthen pans: a dark grey powder will be found on its ſurface. Keep ſtirring the metal inceſſantly till it be wholly converted into ſuch a powder, which is the *Calx of Lead.*

OBSERVATIONS.

As Lead is a very fuſible metal, and in that reſpect greatly reſembles Tin, moſt of the obſervations we made on the calcination of Tin may be applied here.

In the calcination of all metals, and particularly in this of Lead, there appears a ſingular phenomenon which is not eaſily accounted for. It is this: though theſe matters loſe a great deal of their ſubſtance, either by the diſſipation of their phlogiſton, or becauſe ſome of the metal, perhaps, exhales in vapours, yet when the calcination is over their calxes are found to be encreaſed in weight, and this increaſe is very conſiderable. An hundred pounds of Lead, for example, converted into Minium, which is nothing but a calx of Lead brought to a red colour by continuing the calcination, are found to gain ten pounds weight; ſo that for an hundred pounds of Lead we have one hundred and ten pounds of Minium: a prodigious and almoſt incredible augmentation, if it be conſidered that, far from adding any thing to the Lead, we have on the contrary diſſipated part of it.

To account for this phenomenon Natural Philoſophers and Chymiſts have invented ſeveral ingenious hypotheſes, but none of them entirely ſatisfactory.

As we have no eſtabliſhed theory to proceed upon, we ſhall not undertake to explain this extraordinary fact.

PROCESS IV.

To prepare Glaſs of Lead.

TAKE two parts of Litharge, and one part of pure cryſtalline Sand; mingle them together as exactly as poſſible, adding a little Nitre and Sea-ſalt: put this mixture into a crucible of the moſt ſolid and moſt compact earth. Shut the crucible with a cover that may perfectly cloſe it.

Set the crucible thus prepared in a melting furnace; fill the furnace with coals; light the fire gradually, ſo that the whole may be ſlowly heated: then raiſe the fire ſo as to make the crucible very red, and bring the matter it contains into fuſion; keep it thus melted for a quarter of an hour.

Then take the crucible out of the furnace, and break it: in the bottom thereof you will moſt commonly find a ſmall button of Lead, and over it a tranſparent Glaſs, of a yellow colour nearly reſembling that of amber. Separate this Glaſs from the little button of metal, and from the ſaline matters which you will find above it.

OBSERVATIONS.

PURE Lead, being expoſed to a ſtrong fire without any additament, turns to Litharge; which is a ſcaly ſort of ſubſtance, more or leſs yellowiſh, ſhining, and ſoft to the touch. This is the firſt advance to the Vitrification of Lead. The large refineries of Gold and Silver by the means of Lead furniſh a great quantity of this material. It is ſometimes whitiſh, and is then called *Litharge of Silver*; ſometimes yellow, and then bears the name of *Litharge of Gold*. The difference of its colour depends on the degree of fire it hath undergone, and on the metalline ſubſtances vitrified with it.

Litharge alone is very fuſible, and being expoſed to the fire is eaſily converted into Glaſs: but this Glaſs of Lead, made without additament, is ſo active, ſo penetrating, and ſo apt to ſwell, that it can ſcarcely be made uſe of when pure. We are obliged in ſome ſort to clog it, by uniting it with ſome vitrifiable matter that is not ſo ſubtile, ſuch as Sand; and it is for this reaſon, not to render the mixture more fuſible, that we have directed the addition of one third part of Sand to two thirds of Litharge.

The Nitre and Sea-ſalt, preſcribed as ingredients in the mixture, are deſigned to procure an equal fuſion of the whole. For, as the Sand is lighter and leſs fuſible than the Litharge, it will partly riſe towards the upper part of the crucible when that matter firſt begins to flow; in conſequence whereof the contents of the upper part will be much more difficult to melt, and form a Glaſs much more compact than that below: but the Nitre and Sea-ſalt poſſeſſing the upper part of the crucible, becauſe they are ſtill lighter than the Sand, and being in their own nature very efficacious fluxes, on account of their great fuſibility, they quickly bring about the fuſion of thoſe particles of Sand, which, having eſcaped the action of the Litharge, may have riſen unvitrified to its ſurface.

The moſt difficult thing to procure, and yet the moſt neceſſary to the ſucceſs of this operation, is a crucible of earth ſo firm and compact as not to be penetrated by the Glaſs of Lead, which corrodes and makes its way through every thing.

The precaution of chuſing a crucible that ſhall contain a good deal more than the matter to be vitrified is a neceſſary one, becauſe Litharge and Glaſs of Lead are very apt to ſwell.

The rule to keep the crucible cloſe ſhut is alſo indiſpenſably neceſſary, to prevent any bit of charcoal, or other inflammable matter, from falling into it; for when this happens it occaſions a reduction of the Lead, which is always attended with a ſort of effervescence, and ſuch a conſiderable heaving, that commonly moſt of the mixture runs over the crucible. For the ſame reaſon it is very proper, before you expoſe the mixture to the fire, to examine whether or no it contains any matter capable of furniſhing a phlogiſton during the operation; and if it does, to remove that matter with great care.

The little button of Lead, found at the bottom of the crucible after the operation, comes from a ſmall portion of Lead that is commonly left in Litharge, unleſs you prepare it carefully yourſelf, and do not take it from the fire till you are ſure of having deſtroyed all the Lead. Beſides, this ſmall portion of Lead can be of no prejudice to the operation, becauſe it cannot communicate its phlogiſton to the reſt of the matter.

The revivifying of Litharge, of the Calx, and of the Glaſs of Lead, may be obtained by the ſame proceſſes as the reduction of its ore.

PROCESS V.

Lead diſſolved by the Nitrous Acid.

PUT into a matraſs ſome *Aqua Fortis* precipitated like that uſed to diſſolve Silver; weaken it by mixing therewith an equal quantity of common water; ſet the matraſs in a hot ſand-bath; throw into it, little by little, ſmall bits of Lead, till you ſee that no more will diſſolve. *Aqua Fortis* thus lowered will diſſolve about a fourth of its weight of Lead.

There is gradually formed upon the Lead, as it diſſolves, firſt a grey powder, and afterwards a white cruſt, which at laſt hinder the ſolvent from acting on the remaining part of the metal; and therefore the liquor ſhould be made to boil, and the veſſel ſhould be ſhaken to remove thoſe impediments, by which means all the Lead will be diſſolved.

OBSERVATIONS.

LEAD very much reſembles Silver, with reſpect to the phenomena which attend its diſſolution in Acids. For example, the Nitrous Acid muſt be very pure and uncontaminated with the Vitriolic or Marine Acid, to qualify it for keeping the Lead in ſolution: for, if it be mixed with either the one or the other of theſe Acids, the Lead will precipitate in the form of a white powder as faſt as it diſſolves; which is juſt the caſe with Silver.

If the Vitriolic Acid be mixed with the Nitrous, the precipitate will be a combination of the Vitriolic Acid with Lead; that is, a Neutral Metallic Salt, or Vitriol of Lead. If the Acid of Sea-ſalt be mixed therewith, the precipitate will be a *Plumbum corneum*; that is, a Metallic Salt reſembling the *Luna cornea*.

When all the Lead is diſſolved as above deſcribed, the liquor appears milky. If it be kept warm over the fire till little cryſtals begin to appear on its ſurface, and afterwards left to ſtand quiet, in a certain time there will be found at the bottom a greyiſh powder, which being tried on Gold is Mercurial enough to whiten it. Little globules of Quick-ſilver are even diſcernible in it.

We owe this obſervation, together with this manner of proving the exiſtence of Mercury in Lead, and of procuring it from thence, to M. Groſſe, who hath given an account of his proceſs in the Memoirs of the Academy of Sciences, from whence we have copied the deſcription of the operation in hand.

The ſolution being quickly poured off by inclination from the grey mercurial precipitate is ſtill milky, and depoſites another white ſediment. When this ſecond precipitate falls the liquor becomes clear and limpid, and is then of a fine yellow colour, like a ſolution of Gold. On this gold-coloured ſolution, and on the two precipitates above-mentioned, M. Groſſe made ſeveral obſervations, the chief of which we ſhall here inſert.

The yellow liquor affects the tongue at firſt with a taſte of ſweetneſs; but afterwards vellicates it very ſmartly, and leaves on it a ſtrong ſenſation of acrimony, which continues for a long time.

Alkalis precipitate the Lead ſuſpended in this liquor, juſt as they do all other metals diſſolved by Acids; and this precipitate of Lead is white.

Sea-ſalt, or Spirit of Salt, ſeparates the Lead from its ſolvent, and precipitates it, as we obſerved before, into a *Plumbum corneum*: but this precipitate differs from the *Luna cornea*, as being very ſoluble in water; whereas the *Luna cornea* will not diſſolve in it at all; or at leaſt diſſolves therein with great difficulty and in a very ſmall quantity. This *Plumbum corneum* diſſolved in water is again precipitated by the Vitriolic Acid. M. Groſſe obſerves that this forms an exception to the eighth column of Mr. Geoffroy's Table of Affinities; in which the Acid of Sea-ſalt is marked as having a greater affinity than any other Acid with Metallic ſubſtances.

Our ſolution of Lead is alſo precipitated in a white powder by ſeveral Neutral Salts; ſuch as Vitriolated Tartar, Alum, and common Vitriol. It is by the means of double affinities that theſe Neutral Salts effect this precipitation.

Even pure water alone is capable of precipitating the Lead of our ſolution, by weakening the Acid, and thereby diſabling it from keeping the metal ſuſpended.

Laſtly, as all the ſolutions of metals in Acids are nothing but Neutral Metallic Salts in a fluid form, ſo if the ſolution of Lead be evaporated over the fire, it will ſhoot into very beautiful cryſtals, about the bigneſs of hemp-ſeed, ſhaped like regular pyramids having ſquare baſes. Theſe cryſtals are yellowiſh, and have a ſweet ſaccharine taſte: but what is moſt ſingular in them is, that, as they conſiſt of the Nitrous Acid combined with Lead, which manifeſtly contains a great deal of phlogiſton, they conſtitute a Nitrous Metallic Salt, which has the property of deflagrating in a crucible, without the addition of any other inflammable matter. This Salt is extremely hard to diſſolve in water.

The grey mercurial precipitate which whitens Gold, and in which little globules of running Mercury are perceivable, is far from being pure Mercury. This metallic ſubſtance makes but a ſmall part thereof: for it is an aſſemblage 1. of little cryſtals of the ſame nature with thoſe afforded by the evaporated ſolution; 2. of a portion of the white matter, or powder, which renders the ſolution milky; 3. of a grey powder which M. Groſſe conſiders as the only mercurial part; 4. and laſtly, of little particles of Lead that have eſcaped the action of the ſolvent; eſpecially if a little more Lead than the Acid is capable of diſſolving were added with a view to ſaturate it entirely, as in the preſent proceſs.

By means of motion and heat the ſmall parcels of Mercury may be amalgamated with the Lead.

That Mercury ſhould be found intire and in globules in the Spirit of Nitre, which very eaſily diſſolves that metallic ſubſtance, will not be ſurprizing to thoſe who reflect that, in the preſent caſe, the Acid is ſaturated with Lead, with which it has a greater affinity than with Mercury; as appears by

M. Geoffroy's Table of Affinities, where, in the column that hath the Nitrous Acid at top, Lead is placed above Mercury. Agreeably to this, if Lead be preſented to a ſolution of Mercury in Spirit of Nitre, the Lead will be diſſolved, and as the diſſolution thereof advances the Mercury will precipitate.

Hence it appears that, in order to find any Mercury in the ſpontaneous precipitate of Lead diſſolved by the Nitrous Acid, it is neceſſary that the Acid be entirely ſaturated with Lead; or elſe that portion of the Acid which remains unſaturated will diſſolve the Mercury.

With regard to the white powder that renders the ſolution milky, and afterwards precipitates, it is nothing but a portion of the Lead, which, not being intimately united with the Acid, falls in part of its own accord. It is a ſort of calx of Lead, which being expoſed to the fire becomes partly glaſs, and partly Lead, becauſe it ſtill retains ſome of its phlogiſton.

CHAP. VII.

Of MERCURY.

PROCESS I.

To extract Mercury from its Ore, or to revivify it from Cinabar.

PULVERIZE the Cinabar from which you would extract the Mercury; with this powder mix an equal part of clean iron filings; put the mixture into a retort of glaſs or iron, leaving at leaſt one third part thereof empty. Set the retort thus prepared in a ſand-bath, ſo that its body may be quite buried in the ſand, and its neck decline conſiderably downwards: fit on a receiver half filled with water, and let the noſe of the retort enter about half an inch into the water.

Heat the veſſels ſo as to make the retort moderately red. The Mercury will riſe in vapours, which will condenſe into little drops, and fall into the water in the receiver. When you ſee that nothing more comes over with this degree of heat, increaſe it, in order to raiſe what Mercury may ſtill be left. When all the Mercury is thus brought over, take off the receiver, pour out the water contained in it, and collect the Mercury.

OBSERVATIONS.

MERCURY is never mineralized in the bowels of the earth by any thing but Sulphur; with which it forms a compound of a browniſh red colour, known by the name of *Cinabar.*

Sometimes it is only mixed with earthy and ſtony matters that contain no Sulphur; but as this metallic ſubſtance is never deſtitute of its phlogiſton, it then has its metalline form and properties. When it is found in this condition, nothing is more eaſy than to ſeparate it from thoſe heterogeneous matters. For that purpoſe no more is requiſite than to diſtill the whole with a fire ſtrong enough to raiſe the Mercury in vapours. This mineral is volatile; the earthy and ſtony matters are fixed; and a certain degree of heat will effect a complete ſeparation of what is volatile from what is fixed.

This is not the caſe when Mercury is combined with Sulphur: for this latter mineral is volatile as well as Mercury; and the compound reſulting from the union of them both is alſo volatile: ſo that if Cinabar were expoſed to the fire in cloſe veſſels, as it muſt be to ſave the Mercury, it would be ſublimed in ſubſtance, without being decompoſed at all.

In order therefore to ſeparate theſe two ſubſtances from each other, we muſt have recourſe to the interpoſition of ſome third, which hath a greater affinity with one of them than the other hath, and no affinity with that other.

Iron hath all the conditions requiſite for this purpoſe; ſeeing it hath, as may be ſeen in the Table, a much greater affinity with Sulphur than Mercury hath, and is incapable of contracting any union with Mercury.

Iron, however, is not the only ſubſtance that may be employed on this occaſion: Fixed Alkalis, Abſorbent earths, Copper, Lead, Silver, Regulus of Antimony, have all, as well as Iron, a greater affinity than Mercury with Sulphur. Nay, ſeveral of theſe ſubſtances, namely, the ſaline and earthy Alkalis, as well as Regulus of Antimony, cannot contract any union with Mercury: the reſt, to wit, Copper, Lead, and Silver, are indeed capable of amalgamating with Mercury; but then the union which theſe metals contract with the Sulphur prevents it; and even tho' they ſhould unite with this metallic ſubſtance, the degree of heat to which the whole mixture is expoſed would ſoon carry up the Mercury, and ſeparate it with eaſe from thoſe fixed ſubſtances.

In this diſtillation the ſame cautions muſt be obſerved as in all others: that is, the veſſels muſt be ſlowly heated, eſpecially if a glaſs retort be uſed; the fire muſt be raiſed by degrees, and a much ſtronger one applied at laſt than at firſt. This operation particularly requires a very ſtrong degree of fire, when there is but a ſmall quantity of Mercury left.

After the operation there remains in the retort a compound of Iron and Sulphur, which may eaſily be converted into a *crocus*, by calcining it and burning away the Sulphur.

If a Fixed Alkali be employed, a Liver of Sulphur will be found in the retort after the diſtillation.

If the Cinabar from which you extract the Mercury be good, you will generally obtain ſeven eighths of its weight in Quick-ſilver.

In the preſent operation it is not neceſſary to lute on the receiver, becauſe the water, in which the noſe of the retort is plunged, is ſufficient to fix the Mercurial vapours. In caſe the Cinabar, from which you intend to ſeparate the Mercury, be mixed with a great quantity of heterogeneous, but fixed, matters, ſuch as earths, ſtones, &c. it may be ſeparated from them by ſubliming it with a proper degree of heat, becauſe it is volatile.

The vapours of Mercury are prejudicial, and may excite a ſalivation, tremors, and palſies; they ſhould therefore be always avoided by ſuch as work on this mineral.

The oldeſt and richeſt mine of Mercury is that of Almaden in Spain. It is a ſingular property of that mine that, though the Mercury found in it is combined with Sulphur, and in the form of Cinabar, yet no additament is required to procure the ſeparation of theſe two; the earthy and ſtony matter, with which the particles of the ore are incorporated, being itſelf an excellent abſorbent of Sulphur.

In the Quick-ſilver works carried on at this mine they make no uſe of retorts. They place lumps of the ore on an iron grate, which ſtands immediately over the furnace. The furnaces which ſerve for this operation are cloſed at the top by a ſort of dome, behind which ſtands the ſhaft of a chimney that communicates with the fire place, and gives vent to the ſmoke. Theſe furnaces have in their fore-ſide ſixteen apertures, to each of which is luted an aludel in a horizontal poſition, communicating with a long row of other aludels placed likewiſe in an horizontal direction; which aludels ſo connected together form one long pipe or canal, the further end whereof opens into a chamber deſtined to receive and condenſe all the mercurial vapours. Theſe rows of aludels are ſupported from end to end by a terraſs, which runs from the body of the building, wherein the furnaces are erected, to that where the chambers are built that perform the office of receivers.

This is a very ingenious contrivance and ſaves much labour, expence, and trouble, that would be unavoidable if retorts were employed.

That part of the furnace which contains the lumps of ore, ſerves for the body of the retort; the row of aludels for its neck; and the little chambers in which theſe canals terminate are actual receivers. The terraſs of communication, which reaches from the one building to the other, is formed of two inclined planes, the lower edges of which, meeting in the middle of the terraſs, riſe from thence inſenſibly; the one quite to the building where the furnaces are, and the other to that which forms the recipient chambers. By this means, when any Mercury eſcapes through the joints of the aludels, it naturally runs down along theſe inclined planes, and ſo is collected in the middle of the terraſs, where the inferiour ſides of the planes meeting together form a ſort of canal, out of which it is eaſily taken up.

The celebrated M. de Juſſieu having viewed the whole himſelf, in a journey he made to this mine, furniſhed us with this deſcription of the work.

PRO-

diſtillation. Having therefore diſſolved your Mercury in the Vitriolic Acid, if you will now prepare the Turbith, you muſt, by continuing to heat the retort, drive over all the liquor into the receiver, and diſtill till nothing remains but a white powdery matter: then break the retort; pulverize its contents in a glaſs mortar, and thereon pour common water, which will immediately turn the white matter of a lemon-colour; waſh this yellow matter in five or ſix warm waters, and it will be what is called in medicine *Turbith mineral*; that is, a combination of the Vitriolic Acid with Mercury, five or ſix grains whereof is a violent purgative, and alſo an emetick; qualities which it poſſeſſes in common with the vegetable Turbith, whoſe name it hath therefore taken.

There riſes out of the retort, both while the Mercury is diſſolving, and while the ſolvent is abſtracting, a weak Spirit of Vitriol; becauſe a great part of the Acid remains united with the Quick-ſilver, which at laſt appears in the form of a white powder: ſo that, if you do not incline to ſave the Acid which riſes on this occaſion, you may, inſtead of drawing off the liquor in a retort, evaporate it in a glaſs baſon ſet on a ſand-bath, which will be much ſooner done.

It is very remarkable that, on this occaſion, the Mercury may be expoſed, without any danger of ſubliming, to a much greater heat than it is capable of bearing when not combined with the Vitriolic Acid; which ſhews that this Acid hath the property of fixing Mercury to a certain degree.

The white matter, that remains after the evaporation of the fluid, is one of the moſt violent corroſives, and would prove an actual poiſon if taken internally. By waſhing it ſeveral times in warm water it is freed from a great deal of its Acid, and ſo conſiderably ſweetened. The proof is this; if the water uſed in waſhing the Turbith be evaporated, ed, there remains after the evaporation a matter in form of a Salt, that being ſet in a cellar runs into a liquor called *Oil of Mercury*, which is a powerful corroſive. Several authors further direct Spirit of Wine to be burnt on the Turbith, to ſweeten it ſtill more.

If inſtead of waſhing the white matter that remains after the moiſture is drawn off, freſh Oil of Vitriol be poured on it, and then abſtracted as before; this treatment being repeated two or three times, there will at laſt remain in the retort a matter having the appearance of an Oil, which reſiſts the action of the fire, and cannot be deſiccated: qualities which are owing to the great quantity of Acid particles thus united with the Mercury. This Oil of Mercury is one of the moſt violent corroſives. The Mercury may be ſeparated therefrom, by precipitating it with an Alkali, or a metallic ſubſtance that hath more affinity than Mercury with the Vitriolic Acid: Iron, for inſtance, may be employed in this precipitation. Mercury thus ſeparated from the Vitriolic Acid need only be diſtilled to recover the form of Quick-ſilver.

PROCESS IV.

To combine Mercury with Sulphur. Æthiops Mineral.

MIX a dram of Sulphur with three drams of Quick-ſilver, by triturating the whole in a glaſs mortar with a glaſs peſtle. By degrees, as you triturate, the Mercury will diſappear, and the matter will acquire a black colour. Continue the triture till you cannot perceive the leaſt particle of running Mercury. The black matter you will then have in the mortar is known in medicine by the name of *Æthiops mineral*. An Æthiops may alſo be made by fire in the following manner.

In a ſhallow unglazed earthen pan melt one part of flowers of Sulphur: add three parts of running Mercury, making it fall into the pan in the form of ſmall rain, by ſqueezing it through chamoy leather. Keep ſtirring the mixture with the ſhank of a tobacco-pipe all the while the Mercury is falling: you will ſee the matter grow thick and acquire a black colour. When the whole is thoroughly mixed, ſet fire to it with a match, and let as much of the Sulphur burn away as will flame.

OBSERVATIONS.

MERCURY and Sulphur unite together with great eaſe; cold triture alone is ſufficient to join them. By this means the Mercury is reduced into exceeding ſmall atoms, and combines ſo perfectly with the Sulphur that the leaſt veſtige thereof is not to be ſeen.

Sulphur is not the only matter which being rubbed with Mercury will deſtroy its form and fluidity: all fat ſubſtances that have any degree of conſiſtence, ſuch as the fat of animals, balſams, and reſins, are capable of producing the ſame effect. This metallic ſubſtance, being triturated for ſome time in a mortar with theſe matters, becomes at laſt inviſible, and communicates to them a black colour. When thus divided by the interpoſition of heterogeneous particles it is ſaid to be *Killed*. But Mercury doth not contract ſuch an intimate union with theſe other matters as it doth with Sulphur.

The Æthiops prepared by fuſion is a more perfect and accurate combination of Mercury and Sulphur than the other: for, the quantity of Sulphur directed to be uſed in making it being much greater than is abſolutely neceſſary to fix the Mercury, the redundant Sulphur is deſtroyed by burning, and none left but what is moſt intimately united with the Mercury, and hindered by the union it hath contracted with that metallic ſubſtance from being ſo eaſily conſumed. The Æthiops therefore, which is prepared by fuſion and burning the Sulphur, contains a much greater proportion of Mercury than that which is made by ſimple triture; ſo that in Medicine it ought to be preſcribed in different caſes, and in ſmaller doſes.

If no more Sulphur than is juſt neceſſary to kill the Mercury be added to it at firſt, it will be difficult to obtain a perfect mixture; becauſe that quantity is very ſmall: it is better therefore to employ at once the quantity above directed.

PROCESS V.

To ſublime the combination of Mercury and Sulphur into Cinabar.

GRIND to powder Æthiops mineral prepared by fire. Put it into a cucurbit; fit thereto a head; place it in a ſand-bath, and begin with applying ſuch a degree of heat as is requiſite to ſublime Sulphur. A black matter will riſe, and adhere to the ſides of the veſſel. When nothing more will riſe with this degree of heat, raiſe the fire ſo as to make the ſand and the bottom of the cucurbit red; and then the remaining matter will ſublime in the form of a browniſh red maſs, which is true *Cinabar*.

OBSERVATIONS.

ÆTHIOPS mineral requires nothing but ſublimation to become true Cinabar, like that found in Quick-ſilver mines: but our Æthiops contains ſtill more Sulphur than ought to be in the compoſition of Cinabar; for which reaſon we have directed the degree of fire applied at firſt to be no greater than that which is capable of ſubliming Sulphur. As Cinabar, though conſiſting of Mercury and Sulphur, is yet much leſs volatile than either of theſe ſubſtances alone; which probably ariſes from the Vitriolic Acid contained in the Sulphur; therefore, if there be any redundant Sulphur in the Æthiops, which hath not contracted an intimate union with the Mercury, it will ſublime by itſelf in this firſt degree of heat. Some mercurial particles alſo will riſe with it, and give it a black colour.

Cinabar contains no more Sulphur than about a ſixth or ſeventh part of its weight: ſo that, inſtead of employing the common Æthiops to make it, it would be better to prepare one on purpoſe that ſhould contain much leſs Sulphur; becauſe too much Sulphur prevents the ſucceſs of the operation by blackening the Sublimate. Indeed in what ever manner you go about it, the Cinabar always appears black at firſt: but when it is well prepared, and contains no more than its due proportion of Sulphur, the blackneſs is only external. This black coat therefore may be taken off; and then the internal part will appear of a fine red, and, if ſublimed a ſecond time, will be very beautiful.

As artificial Cinabar hath the ſame properties with the native, it may be decompoſed by the ſame means: ſo that, if you want to extract the Mercury out of it, recourſe muſt be had to the proceſs above delivered for working on Cinabar ores.

PROCESS VI.

To diſſolve Mercury in the Nitrous Acid. Sundry Mercurial Precipitates.

PUT into a matraſs the quantity of Mercury you intend to diſſolve: pour on it an equal quantity of good Spirit of Nitre, and ſet the matraſs in a ſand-bath moderately heated. The Mercury will diſſolve with the phenomena that uſually attend the diſſolutions of metals in this Acid. When the diſſolution is completed let the liquor cool. You will know that the Acid is perfectly ſaturated, if there remain at the bottom of the veſſel, notwithſtanding the heat, a little globule of Mercury that will not diſſolve.

OBSERVATIONS.

MERCURY diſſolves in the Nitrous Acid with much more facility, and in much greater quantity, than in the Vitriolic; ſo that it is not neceſſary, on this occaſion, to make the liquor boil. This ſolution when cold yields cryſtals, which are a Nitrous Mercurial Salt. If you deſire to have a clear limpid ſolution of Mercury, you muſt employ an *Aqua Fortis* that is not tainted with the Vitriolic or Marine Acid: for, the affinity of theſe two Acids with Mercury being greater than that of the Nitrous Acid, they precipitate it in the form of a white powder, when they are mixed with the ſolvent.

Mercury thus precipitated in a white powder, out of a ſolution thereof in the Spirit of Nitre, is uſed in Medicine. To obtain this precipitate, which is known by the name of the *White Precipitate*, Sea-ſalt diſſolved in water together with a little Sal Ammoniac is uſed; and the precipitate is waſhed ſeveral times in pure water, without which precaution it would be corroſive, on account of the great quantity of the Marine Acid which it would contain.

The preparation known by the name of *Red Precipitate* is alſo obtained from our ſolution of Mercury in Spirit of Nitre. It is made by abſtracting all the moiſture of the ſolution, either by diſtillation in a retort, or by evaporation in a glaſs baſon ſet on a ſand-bath. When it begins to grow dry it appears like a white ponderous maſs. Then the fire is made ſtrong enough to drive off almoſt all the Nitrous Acid, which, being now concentrated, riſes in the form of red vapours. If theſe vapours be catched in a receiver, they condenſe into a liquor, which is a very ſtrong and vaſtly ſmoking Spirit of Nitre.

By degrees, as the Nitrous Acid is forced up by the fire, the mercurial maſs loſes its white colour, and becomes firſt yellow, and at laſt very red. When it is become entirely of this laſt colour the operation is finiſhed. The red maſs remaining is a Mercury that contains but very little Acid, in compariſon of what it did while it was white: and indeed the firſt white maſs is ſuch a violent corroſive, that it cannot be uſed in Medicine; whereas, when it is become red, it makes an excellent eſcharotic, which thoſe who know how to uſe it properly apply with very great ſucceſs, particularly to venereal ulcers.

This preparation is very improperly called a *Precipitate:* for the Mercury is not ſeparated from the Spirit of Nitre by the interpoſition of any other ſubſtance, but only by evaporating the Acid. It is alſo called *Arcanum Corallinum.*

It muſt be obſerved that Mercury, by its union with the Nitrous Acid, acquires a certain degree of fixity: for the red precipitate is capable of ſuſtaining, without being volatilized, a ſtronger degree of heat than pure Mercury can; which, as we obſerved before, is the property of Turbith mineral alſo.

PROCESS VII.

To combine Mercury with the Acid of Sea-ſalt. Corroſive Sublimate.

EVAPORATE a ſolution of Mercury in the Nitrous Acid till there remain only a white powder, as mentioned in our obſervations on the preceding proceſs. With this powder mix as much Green Vitriol calcined to whiteneſs, and decrepitated Sea-ſalt, as there was Mercury in the ſolution.

Triturate the whole carefully in a glaſs mortar. Put this mixture into a matraſs, ſo that two thirds thereof may remain empty, having firſt cut off the neck to half its length; or inſtead thereof you may uſe an apothecary's phial. Set your veſſel in a ſand-bath, and put ſand round it as high as the contents reach. Apply a moderate fire at firſt, and raiſe it by ſlow degrees. Vapours will begin to aſcend. Continue the fire in the ſame degree till they ceaſe. Then ſtop the mouth of the veſſel with paper, and increaſe the fire till the bottom of the ſand-bath be red-hot. With this degree of heat a Sublimate will riſe, and adhere to the inſide and upper part of the veſſel, in the form of white, ſemi-tranſparent cryſtals. Keep up the fire to the ſame degree till nothing more ſublimes. Then let the veſſel cool; break it, and take out what is ſublimed, which is *Corroſive Sublimate.*

OBSERVATIONS.

IN this operation the mineral Acids act, and are acted upon, in a remarkable manner. Every one of the three is at firſt neutralized, or united with a different baſis; the Vitriolic being combined with Iron; the Nitrous with Mercury, forming therewith a Nitrous Mercurial Salt; and the Marine with its natural Alkaline baſis. The Vitriolic and Nitrous Acids, which are united with metalline ſubſtances, being both ſtronger than the Acid of Sea-ſalt, ſtrive to expel it from its baſis, in order to combine with it themſelves; but the Vitriolic Acid, being the ſtrongeſt of the two, would take ſole poſſeſſion of this baſis excluſive of the Nitrous, which would continue united with the Mercury if the Marine Acid had not a greater affinity than the Nitrous with this metallic ſubſtance. This Acid therefore being expelled from its baſis by the Vitriolic Acid, and ſo ſet at liberty, muſt unite with the Mercury, and ſeparate the Nitrous Acid from it; which now hath no reſſource but to unite with the Iron deſerted by the Vitriolic Acid. But as all theſe changes are brought about by the means of a conſiderable heat, and as the Nitrous Acid hath not a very firm coheſion with the Iron, it is driven off by the force of the fire; and this it is which we ſee riſe in vapours during the operation. It alſo carries off with it ſome parts of the other two Acids, but in a very ſmall quantity. After the operation therefore there remains 1. A combination of the Vitriolic Acid with the baſis of Sea-ſalt; that is a Glauber's Salt: 2. A red martial earth, being that which was the baſis of the Vitriol: theſe two ſubſtances are blended together, and remain at the bottom of the veſſel becauſe of their fixity: 3. A combination of the Marine Acid with Mercury; both of which being volatile, they aſcend together into the upper part of the veſſel, and there form a Corroſive Sublimate.

If we reflect on this proceſs with attention, and recollect diſtinctly the affinities of the different ſubſtances employed in it, we ſhall perceive that it is not neceſſary to make uſe of all thoſe matters, and that the operation would ſucceed though ſeveral of them were left out.

Firſt, the Nitrous Acid may be omitted; ſince, as hath been ſhewn, it is not an ingredient in the Sublimate, but is diſſipated in vapours during the operation. From an accurate mixture therefore of Vitriol, Sea-ſalt, and Mercury, a Corroſive Sublimate muſt be obtained: for as the Acid of the Vitriol will diſengage the Acid of Sea-ſalt, the latter will be at liberty to combine with the Mercury, and ſo form the compound we are in queſt of.

Secondly, if we make uſe of Mercury diſſolved by the Nitrous Acid, we may omit the Vitriol; becauſe the Nitrous Acid having a greater affinity than the Marine Acid itſelf with the baſis of Sea-ſalt, and the Acid of Sea ſalt having a greater affinity than the Nitrous Acid with Mercury, theſe two Acids will naturally make an exchange of the baſes with which they are united: the Nitrous will lay hold on the baſis of Sea-ſalt, and form a quadrangular Nitre, while the Marine Acid will join the Mercury, and with it form a Corroſive Sublimate.

Thirdly, inſtead of Sea-ſalt its Acid only may be employed; which being mixed with the ſolution of Mercury in the Spirit of Nitre, will, by virtue of its greater affinity with that metallic ſubſtance, ſeparate it from the Nitrous Acid, unite with it, and form a white mercurial precipitate, which need only be ſublimed to become the combination required.

Fourthly, inſtead of Mercury diſſolved in the Nitrous Acid, Mercury diſſolved by the Vitriolic Acid, or Turbith, may be uſed; only mixing Sea-ſalt therewith: for theſe two ſaline ſubſtances will mutually decompound each other, by virtue of the affinities of their Acids, and for the ſame reaſons that Sea-ſalt and the Mercurial Nitrous Salt decompound each other. The Vitriolic Acid quits the Mercury with which it is combined, to unite with the baſis of the Sea-ſalt; and the Acid of this Salt being expelled by the Vitriolic, combines with the Mercury, and conſequently forms our Corroſive Sublimate. In this caſe a Glauber's Salt remains after the ſublimation.

Theſe ſeveral methods of preparing Corroſive Sublimate are never uſed, becauſe each of them is attended with ſome inconvenience; ſuch as requiring too long triture, yielding a Sublimate leſs corroſive than it ſhould be, or a ſmaller quantity of it. We muſt, however, except the laſt; which was invented by the late Mr. Boulduc, of the Academy of Sciences, who found none of theſe inconveniencies attending it *.

Corroſive Sublimate may alſo be made only by mixing Mercury with Sea-ſalt, without any additament. This may appear ſurprizing when we conſider that, as Acids have a greater affinity with Alkalis than with metallic ſubſtances, the Acid of Sea-

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* See the Memoirs of the Academy for 1730.

ſalt ought not to quit its baſis, which is Alkaline, to unite with Mercury.

In order to explain this phenomenon it muſt be remembered that Sea ſalt, when expoſed to the fire without additament, ſuffers a little of its Acid to eſcape. Now this portion of the Marine Acid unites with the Mercury, and forms a Corroſive Sublimate. Moreover, as there is a pretty ſtrong affinity between the Marine Acid and Mercury, this may help to detach from the Sea-ſalt a greater quantity of Acid than it would otherwiſe part with. Nevertheleſs the quantity of Sublimate obtained by this means is not conſiderable, nor is it very corroſive.

On this occaſion we muſt alſo mention another combination of the Marine Acid with Mercury; which is made by mixing that metallic ſubſtance perfectly with Sal Ammoniac, by the means of triture. Mercury, like all other metals except Gold, poſſeſſes the property of decompounding Sal Ammoniac, ſeparating the volatile Alkali which ſerves it for a baſis, and combining, by the help of a very gentle heat, with its Acid, which is well known to be the ſame with that of Sea-ſalt. This decompoſition of Sal Ammoniac, by the metalline ſubſtances, is a full exception to the firſt column of Mr. Geoffroy's Table of Affinities, and is the baſis of ſeveral new medicines invented by the late Comte de la Garaye *.

Corroſive Sublimate is the moſt violent and the moſt active of all corroſive poiſons. It is never uſed in medicine, but in external applications. It is a powerful eſcharotic; it deſtroys proud fleſh, and cleans old ulcers: but it muſt be uſed by thoſe only who know how to apply it properly, and requires an able hand to manage it. It is not commonly applied by itſelf, but mixed in the proportion of half a dram

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* See the Memoir given in by me on this ſubject to the Academy of Sciences in the *Memoires de l'Academie* 1754.

to a pound of lime-water. This mixture is yellowiſh, and bears the name of *Aqua Phagedenica.*

Water diſſolves Corroſive Sublimate, but in a ſmall quantity. If a Fixed Alkali be mixed with this ſolution, the Mercury precipitates in the form of a red powder. If the precipitate be procured by a Volatile Alkali, it is white; if by Lime-water, it is yellow. This Mercurial Salt diſſolves pretty eaſily in boiling Spirit of Wine.

PROCESS VIII.

Sweet Sublimate.

TAKE four parts of Corroſive Sublimate; pulverize it in a glaſs or marble mortar; add by little and little three parts of Mercury revivified from Cinabar; triturate the whole carefully, till the Mercury be perfectly killed, ſo that no globule thereof can be perceived. The matter will then be grey. Put this powder into an apothecary's phial, or into a matraſs, whoſe neck is not above four or five inches long, leaving two thirds thereof empty. Set the veſſel in a ſand-bath, and put ſand round it to one third of its heighth. Apply a moderate fire at firſt; and afterwards raiſe it gradually till you perceive that the mixture ſublimes. Keep it up to this degree till nothing more will riſe, and then break the veſſel. Reject, as uſeleſs, a ſmall quantity of earth which you will find at the bottom; ſeparate alſo what adheres to the neck of the veſſel, and carefully collect the matter in the middle, which will be white. Pulverize it; ſublime it a ſecond time, in the ſame manner as before; and in the ſame manner ſeparate the earthy matter left at the bottom of the veſſel, and what you find ſublimed into the neck. Pulverize, and ſublime a third time, the white matter you laſt found in the middle. The white matter of this third ſublimation is the *Sweet Sublimate*, called alſo *Aquila Alba.*

OBSERVATIONS.

THE Acid of Sea-ſalt in the Corroſive Sublimate is very far from being perfectly ſaturated with Mercury; and thence comes the corroſive quality of this ſaline compound. But though Mercury, as appears by this combination, is capable of imbibing a much greater quantity of Acid than is neceſſary to diſſolve it; nay, though it naturally takes up this ſuper-abundant quantity of Acid, yet it doth not follow from thence that this redundant Acid may not combine with Mercury to the point of perfect ſaturation, ſo as to loſe its corroſive acidity.

This is the caſe in the operation here deſcribed. A freſh quantity of running Mercury is mixed with Corroſive Sublimate; and the freſh Mercury, combining with the ſuper-abounding Acid, deprives the Sublimate of its acrimony, and forms a compound which comes much nearer the nature of a Neutral Metallic Salt.

Trituration alone is not ſufficient to produce an union between the newly added Mercury and the Acid of the Corroſive Sublimate: becauſe, generally ſpeaking, the Acid of Sea-ſalt cannot diſſolve Mercury without the help of a certain degree of heat, and unleſs it be reduced into vapours.

Thus, though the newly added Mercury becomes inviſible by trituration, and ſeems actually combined with the Corroſive Sublimate, yet the union is not intimate. There is only an interpoſition of parts, but no true diſſolution of the newly added Mercury by the ſuper-abundant Acid of the Corroſive Sublimate. For this reaſon the mixture muſt be ſublimed; and by this ſublimation only is the true union effected. Nor is one ſingle ſublimation ſufficient: no leſs than three are neceſſary to deprive the Sublimate of the corroſive quality which renders it poiſonous. After the third ſublimation, the Sublimate being put upon the tongue gives no conſiderable ſenſation of acrimony; nor doth it retain any more of its former activity than is requiſite to make it a gentle purgative, when adminiſtered from ſix to thirty grains for a doſe.

If a leſs quantity of Mercury than that above directed be mixed with the Corroſive Sublimate, the ſuper-abundant Acid will not be ſufficiently ſaturated; and the leſs Mercury is added, the more of its corroſive virtue will the Sublimate retain.

If, on the contrary, a greater quantity of Mercury be added, there will be more than the Acid can poſſibly diſſolve, and the ſuperfluous quantity will remain in its natural form of Quick-ſilver. It is better therefore to err in the exceſs than in the defect of the proportion of Mercury to be added; becauſe the Corroſive Sublimate will take up no more than is neceſſary to dulcify it.

Part of the Acid of the Corroſive Sublimate is alſo diſſipated in vapours during the operation; and it is neceſſary to allow room for theſe vapours to circulate, and a vent to give them paſſage, or elſe they will burſt the veſſels. Theſe are our reaſons for leaving an empty ſpace in the ſubliming veſſels, and for having their necks no more than five or ſix inches long.

The matter which ſublimes into the neck of the veſſel is always very acrid; for which reaſon it muſt be ſeparated from the Sweet Sublimate. There remains alſo at the bottom of the matraſs an earthy, reddiſh matter; which probably comes from the Vitriol employed in making the Corroſive Sublimate. This matter muſt likewiſe be rejected as uſeleſs after every ſublimation.

PROCESS IX.

The Panacea of Mercury.

PULVERISE ſome Sweet Sublimate, and ſublime it in the ſame manner as you did thrice before. Repeat this nine times. After theſe ſublimations it will make no impreſſion on the tongue. Then pour on it aromatic Spirit of Wine, and ſet the whole in digeſtion for eight days. After that decant the Spirit of Wine, and dry what remains, which is the *Panacea of Mercury*.

OBSERVATIONS.

THE great number of ſublimations, which the Sweet Sublimate is made to undergo, ſweeten it ſtill more, and to ſuch a degree that it leaves no ſenſation on the tongue, nor hath any purgative virtue.

The Spirit of Wine, in which it is digeſted after all the ſublimations, is deſigned to blunt ſtill more the ſharpneſs of any acid particles that may not have been ſufficiently dulcified by the preceding ſublimations.

As Mercury is the ſpecific remedy of venereal diſorders, ſundry preparations thereof have been attempted with a view to produce different efffects. Sweet Sublimate is purgative; and for that reaſon is not quite proper for procuring a ſalivation, becauſe it carries off the humours by ſtool. The Panacea of Mercury, which, on the contrary, is not purgative, may raiſe a ſalivation when taken inwardly.

End of the Firſt Volume.

EXPLANATION

OF THE

PLATES.

PLATE FIRST.

FIG. I. *A Copper Alembic.*

A. The Cucurbite or Body.
B. The Neck.
C. The Head.
D. The Beak, Noſe, or Spout
E. The Refrigeratory, or Cooler.
F. Its Cock.
G. The Receiver.

FIG. II. *A Glaſs Alembic.*

A. The Cucurbite.
B. The Head.
C. The Gutter within the Head.
D. The Beak.

FIG. III. *A long-necked Glaſs Alembic.*

A. The Body of the Matraſs.
B. The Neck.
C. The Head.

PLATE SECOND.

FIG. I. *A Glaſs Alembic of one piece.*

A. The Cucurbite.
B. The Head.
C. The Aperture in the Head.
D. Its Stopple.
E. The Mouth of the Cucurbite.

FIG. II. *A Pelican.*

A. The Cucurbite.
B. The Head.
C. The Aperture in the Head, with its Stopple.
D. D. The two curved Spouts.

FIG. III. *A Row of Aludels.*

FIG. IV. *A Retort.*

A. Its Bowl.
B. Its Neck.

FIG. V. *An Engliſh Retort.*

PLATE THIRD.

FIG. I. *A Reverberating Furnace.*

A. The Aſh-hole Door.
B. The Fire-place Door.
C. C. C. C. Regiſters.
D. The Dome, or Reverberatory.
E. The Conical Funnel.
F. The Retort in the Furnace.
G. The Receiver.
H. H. Iron Bars to ſuſtain the Retort.

FIG. II. *The Conical Funnel by itſelf.*

FIG. III. *Back View of a Muffle.*

A. The bottom of the Muffle.
B Its Arch.
C. C. C. Lateral apertures.

FIG. IV. *Fore-View of a Muffle.*

FIG. V. *A Melting Furnace.*

A. A. The Baſe of the Furnace.
B. The Aſh-hole.
C. D. The Grate for the Fire.
E. The Fire place.

F. G. H. Curvature of the inſide of the upper part of the Fire-place.
I. The Shaft or Chimney.

PLATE FOURTH.

A Cupelling Furnace.

A. The Aſh-hole.
B. B. Its ſliding Doors.
C. The Fire-place.
D. D. Its ſliding Doors.
E. F. Small apertures in the Sliders.
G. G. Holes for Bars to bear the Muffles.
H. H. H. Iron braces in the forepart of the Furnace, which form grooves for the Doors of the Fire-place and Aſh-hole to ſlide in.
I. The upper pyramidal part of the Furnace.
K. An aperture therein for managing the Coals.
L. The Opening at top.
M. The Pyramidal Cover.
N. The Chimney or end of the Shaft, on which the conical Funnel may be fitted.
O. O. O. O. Handles for moving the ſliding Doors.
P. P. Ears of the Pyramidal Cover.

N. B. The Furnaces, as repreſented in the two laſt Plates, are not in due proportion to each other. The Cupelling Furnace is much larger than it ſhould be, with reſpect to the Melting Furnace. Theſe dimenſions are here given it, only that all its parts might be more diſtinctly expreſſed than could have been done if we had made it leſs.

ERRATA in VOL. I.

P. 18. l. 8. from bottom, for *ſteams* read *ſteam*. p. 52. l. 7. and 8. for *them* read *it*. p. 49. for CHAP. VIII. read CHAP. VII. p. 77. for CHAP. IX. read CHAP. VIII. p. 97. l. 12. for *it from* read *its Acid from*. p. 115. l. 10 for *Tartarized* read *Alkoholized*. p. 126. l. 9. for *ſea-weeds* read *maritime plants*. p. 134. l. 21. after *thoſe* read *ſubſtances*. p. 138. l. 17. for *ſubmarine* read *maritime*. p. 149. l. 5. for *its ores* read *its matrices*. p. 150. l. 15. for *ores* read *minerals*: p. 156. l. 17. read *by arſenic*; and l. 4. from bottom; for *metallic* read *unmetallic*. p. 163. l. 5. from bottom for *Acids* read *Acid*. p. 170. l. 11. from bottom, for *cloſe* read *which muſt fill*. p. 171. l. 14. from bottom for *Break* read *Beak*. p. 198. l. 8. for *and more* read *or more*. p. 222. l. 10. dele *by it*. p. 229. l. 6, 7. dele *the* before *moiſture*, and *of the air* after it. p. 248. l. 8, 9. from bottom, for *them* read *it*. p. 285. l. 15. from bottom, dele *of* before *Spirit*. p. 289. l. 21. read *on mixing*. p. 372. l. 12. from bottom, for *unvarniſhed* read *unglazed*. p. 373. l. 6. for *would* read *is*, and dele *be*; l. 7. dele *would* and read *preſents*. p. 383. l. 7. for *afterwards* read *preſently*. p. 406. l. 9. from bottom, dele *on*.

Pl. I.

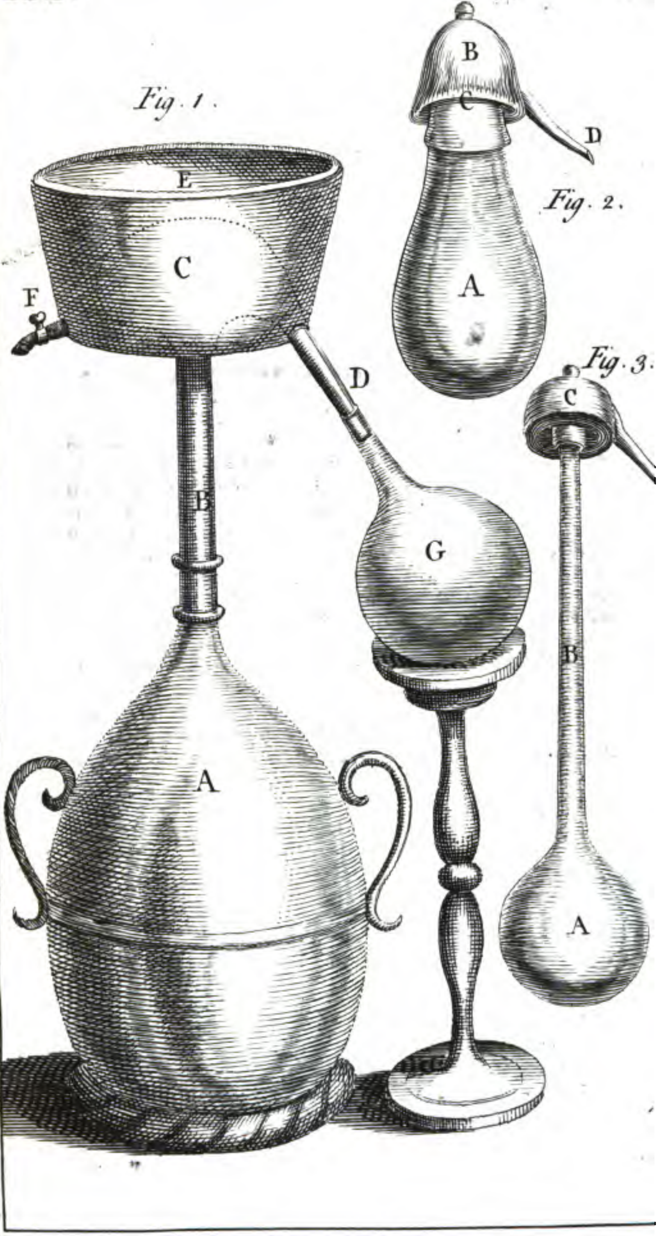

Fig. 1.

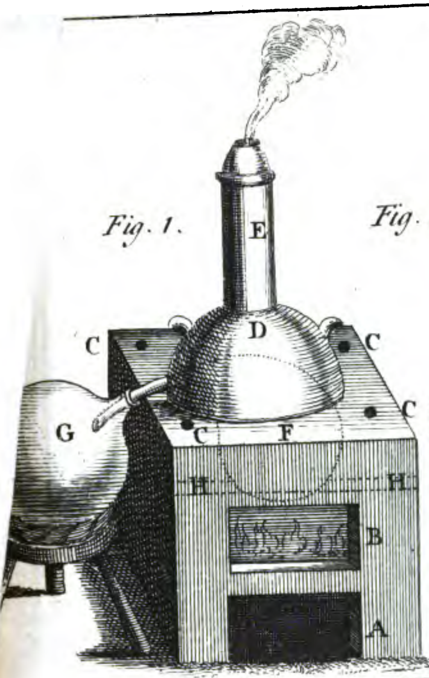

Fig. 2.

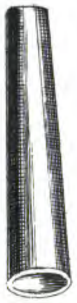

Fig. 5.

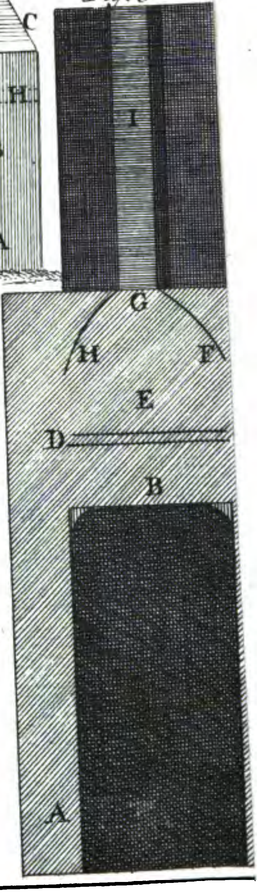

Fig. 3.

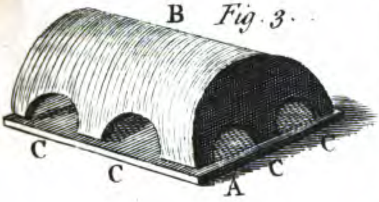

Fig. 4.